MODEL SR530
LOCK-IN AMPLIFIER

MP MASTER
MA30345

STANFORD
RESEARCH
SYSTEMS

No.

MODEL SR530
LOCK-IN AMPLIFIER

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SAFETY AND PREPARATION FOR USE

****CAUTION****

This instrument may be damaged if operated with the LINE VOLTAGE SELECTOR set for the wrong applied ac input-source voltage or if the wrong fuse is installed.

LINE VOLTAGE SELECTION

The SR530 operates from a 100V, 120V, 220V, or 240V nominal ac power source having a line frequency of 50 or 60 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR card, located in the rear panel fuse holder, is set so that the correct ac input voltage value is visible.

Conversion to other ac input voltages requires a change in the fuse holder voltage card position and fuse value. Disconnect the power cord, open the fuse holder cover door and rotate the fuse-pull lever to remove the fuse. Remove the small printed circuit board and select the operating voltage by orienting the printed circuit board to position the desired voltage to be visible when pushed firmly into its slot. Rotate the fuse-pull lever back into its normal position and insert the correct fuse into the fuse holder.

LINE FUSE

Verify that the correct line fuse is installed before connecting the line cord. For 100V and 120V, use a 1/2 Amp fuse and for 220V and 240V, use a 1/4 Amp fuse.

LINE CORD

This instrument has a detachable, three-wire power cord with a three-contact plug for connection to both the power source and protective ground. The protective ground contact connects to the accessible metal parts of the instrument. To prevent electrical shock, always use a power source outlet that has a properly grounded protective-ground contact.

OPERATE WITH COVERS IN PLACE

To avoid personal injury, do not remove the product covers or panels. Do not operate the product without all covers and panels in place.

WARNING REGARDING USE WITH PHOTOMULTIPLIERS

It is relatively easy to damage the signal inputs if a photomultiplier is used improperly with the lock-in amplifier. When left completely unterminated, a PMT will charge a cable to a few hundred volts in a very short time. If this cable is connected to the lockin, the stored charge may damage the front-end transistors. To avoid this problem, provide a leakage path of about 100 KΩ to ground inside the base of the PMT to prevent charge accumulation.

SR530 Specification Summary

General

Power	100, 120, 220, 240 Vac (50/60 Hz); 35 Watts Max
Mechanical	17" x 17" x 5.25" (Rack Mount Included) 16 lbs.
Warranty	Two years parts and labor.

Signal Channel

Inputs	Voltage:	Single-ended or True Differential
	Current:	10^6 Volts/Amp
Impedance	Voltage:	100 MΩ + 25 pF, ac coupled
	Current:	1 kΩ to virtual ground
Full Scale Sensitivity	Voltage:	100 nV (10 nV on expand) to 500 mV
	Current:	100 fA to 0.5 μA
Maximum Inputs	Voltage:	100 Vdc, 10 Vac damage threshold 2 Vac peak-to-peak saturation
	Current:	10 mA damage threshold 1 μA ac peak-to-peak saturation
Noise	Voltage:	7 nV/√Hz at 1 kHz
	Current:	0.13 pA/√Hz at 1 kHz
Common Mode	Range:	1 Volt peak; Rejection: 100 dB dc to 1KHz Above 1KHz the CMRR degrades by 6 dB/Octave
Gain Accuracy	1% (2 Hz to 100KHz)	
Gain Stability	200 ppm/°C	
Signal Filters	60 Hz notch, -50 dB (Q=10, adjustable from 45 to 65 Hz) 120 Hz notch, -50 dB (Q=10, adjustable from 100 to 130 Hz)) Tracking bandpass set to within 1% of ref freq (Q=5)	
Dynamic Reserve	20 dB	LOW (1 μV to 500 mV sensitivity)
	40 dB	NORM (100 nV to 50 mV sensitivity)
	60 dB	HIGH (100 nV to 5 mV sensitivity)
	Bandpass filter adds 20 dB to dynamic reserve Line Notch filters increase dynamic reserve to 100 dB	

Reference Channel

Frequency	0.5 Hz to 100 kHz
Input Impedance	1 MΩ, ac coupled
Trigger	SINE: 100 mV minimum, 1Vrms nominal PULSE: ±1 Volt, 1 μsec minimum width
Mode	Fundamental (f) or 2nd Harmonic (2f)
Acquisition Time	25 Sec at 1 Hz 6 Sec at 10 Hz 2 Sec at 10 kHz

Slew Rate	1 decade per 10 S at 1 kHz
Phase Control	90° shifts Fine shifts in 0.025° steps
Phase Noise	0.01° rms at 1 kHz, 100 msec, 12 dB TC
Phase Drift	0.1°/°C
Phase Error	Less than 1° above 10Hz
Orthogonality	90° ± 1°

Demodulator

Stability	5 ppm/°C on LOW dynamic reserve 50 ppm/°C on NORM dynamic reserve 500 ppm/°C on HIGH dynamic reserve
Time Constants	Pre: 1msec to 100 sec (6 dB/Octave) Post: 1sec, 0.1 sec, none (6 dB/Octave) or none
Offset	Up to 1X full scale (10X on expand) Both channels may be offset
Harmonic Rej	-55 dB (bandpass filter in)

Outputs & Interfaces

Channel 1 Outputs	X (RcosØ), X Offset, R (magnitude), R Offset, X Noise, X5 (external D/A)
Channel 2 Outputs	Y (RsinØ), Y Offset, Ø (phase shift of signal), Y Noise, X6 (external D/A)
Output Meters	2% Precision mirrored analog meter
Output LCD's	Four digit auto-ranging LCD display shows same values as the analog meters
Output BNC's	±10 V output corresponds to full scale input <1 Ω output impedance
X Output	X (RcosØ), ±10 V full scale, < 1Ω output impedance
Y Output	Y (RsinØ), ±10 V full scale, < 1Ω output impedance
Reference LCD	Four digit LCD display for reference phase shift or frequency
RS232	Interface controls all functions. Baud rates from 300 to 19.2 K
GPIB	Interface controls all functions. (IEEE-488 Std)
A/D	4 BNC inputs with 13 bit resolution (±10.24 V)
D/A	2 BNC outputs with 13 bit resolution (±10.24 V)
Ratio	Ratio output equals 10X Channel 1 output divided by the Denominator input.
Internal Oscillator	Range: 1 Hz to 100 kHz, 1% accuracy Stability: 150 ppm/°C Distortion: 2% THD Amplitude: 1% accuracy, 500 ppm/°C stability

Front Panel Summary

Signal Inputs

Single Ended (A), True Differential (A-B), or Current (I)

Signal Filters

Bandpass:	Q-of-5 Auto-tracking filter (In or Out)
Line Notch:	Q-of-10 Notch Filter at line frequency (In or Out)
2XLine Notch:	Q-of-10 Notch Filter at twice line frequency (In or Out)

Sensitivity

Full scale sensitivity from 100 nV to 500 mV RMS for voltage inputs or from 100 fA to 500 nA RMS for current inputs.

Dynamic Reserve

Select	Dynamic Reserve	Stability	Sensitivity Ranges
LOW	20 dB	5 ppm	1 µV to 500 mV
NORM	40 dB	50 ppm	100 nV to 50 mV
HIGH	60 dB	500 ppm	100 nV to 5 mV

Status Indicators

OVLD	Signal Overload
UNLK	PLL is not locked to the reference input
ERR	Illegal or Unrecognized command
ACT	RS232 or GPIB interface Activity
REM	Remote mode: front panel has been locked-out

Display Select

Channel 1	Channel 2
X (RcosØ)	Y (RsinØ)
X Offset	Y Offset
R (Magnitude)	Ø (Phase)
R Offset	Ø (no offset)
X Noise	Y Noise
X5 (D/A)	X6 (D/A)

Analog Meters

Displays Channel 1 and 2 Outputs as a fraction of full scale

Output LCD's

Displays the Channel 1 and 2 Outputs in absolute units

Output BNC's

Channel 1 and 2 Outputs follow Analog Meters, ± 10 V for ± full scale

Expand

Multiplies the Channel 1 or 2 Analog Meter and Output voltage by a factor X1 or X10.

REL

Set the Channel 1 or 2 Offset to null the output: subsequent readings are relative readings. REL with phase display performs auto-phasing. REL with X5, X6 display zeroes the D/A outputs.

Offset

Enables or Disables Offset, and allows any offset (up to full scale) to be entered. X, Y, and R may be offset and X5, X6 may be adjusted. Phase is offset using the reference phase shift.

X BNC

X (RcosØ) output, ± 10V full scale

Y BNC

Y (RsinØ) output, ± 10V full scale

Reference Input

1 MΩ Input, 0.5 Hz to 100 KHz, 100 mV minimum

Reference Trigger

Trigger on rising edge, zero crossing, or falling edge

f/2f Mode

PLL can lock to either X1 or X2 of the reference input frequency

Phase Controls

Adjust phase in smoothly accelerating 0.025° steps, or by 90° steps. Press both 90° buttons to zero the phase.

Reference LCD

Display reference phase setting or reference frequency

Time Constants	Pre-filter has time constants from 1 mS to 100 S (6 dB/Octave) Post-filter has time constants of 0, 0.1 or 1.0 S (6 dB/Octave)
ENBW	Equivalent Noise Bandwidth. Specifies the bandwidth when making Noise measurements. (1Hz or 10 Hz ENBW)
Power Switch	Instrument settings from the last use are recalled on power-up

Abridged Command List

AX	Auto offset X
AY	Auto offset Y
AR	Auto offset R
AP	Auto phase
B	Return Bandpass Filter Status
B0	Take out the Bandpass Filter
B1	Put in the Bandpass Filter
C	Return the Reference LCD Status
C0	Display the Reference Frequency
C1	Display the Reference Phase Shift
D	Return Dynamic Reserve Setting
D0	Set DR to LOW range
D1	Set DR to NORM range
D2	Set DR to HIGH range
En	Return Channel n (1 or 2) Expand Status
En,0	Turn Channel n Expand off
En,1	Turn Channel n Expand on
F	Return the Reference Frequency
G	Return the Sensitivity Setting
G1	Select 10 nV Full-Scale
...	(G1-G3 with SRS preamp only)
G24	Select 500 mV Full-Scale
H	Return Preamp Status (1=installed)
I	Return the Remote/Local Status
I0	Select Local : Front panel active
I1	Select Remote: Front panel inactive
I2	Select Remote with full lock-out
J	Set RS232 End-of-Record to <cr>
Jn,m,o,p	Set End-of-record to n,m,o,p
K1	Simulates Key-press of button #1
...	(see un-abridged command list)
K32	Simulates Key-press of button #32
L1	Return Status of Line Notch Filter
L1,0	Remove Line Notch Filter
L1,1	Insert Line Notch Filter
L2	Return Status of 2XLine Filter
L2,0	Remove 2XLine Notch Filter
L2,1	Insert 2XLine Notch Filter
M	Return the f/2f Status
M0	Set reference mode to f
M1	Set reference mode to 2f
N	Return the ENBW setting
N0	Select 1 Hz ENBW
N1	Select 10 Hz ENBW
OX	Return X Offset Status
OX 0	Turn off X Offset
OX 1,v	Turn on X Offset, v = offset
OY	Return Y Offset Status
OY 0	Turn off Y Offset
OY 1,v	Turn on Y Offset, v = offset
OR	Return R Offset Status
OR 0	Turn off R Offset
OR 1,v	Turn on R Offset, v = offset
P	Return the Phase Setting
Pv	Set the Phase to v. Abs(v) < 999 deg
Q1	Return the Channel 1 output
Q2	Return the Channel 2 output
QX	Return the X Output
QY	Return the Y Output
R	Return the trigger mode
R0	Set the trigger for rising edge
R1	Set the trigger for + zero crossing
R2	Set the trigger for falling edge
S	Return the display status
S0	Display X and Y
S1	Display X and Y Offsets
S2	Display R and Ø
S3	Display R Offset and Ø
S4	Display X and Y noise
S5	Display X5 and X6 (ext D/A)
T1	Return pre-filter setting
T1,1	Set the pre-filter TC to 1 mS
...	
T1,11	Set the pre-filter TC to 100 S
T2	Return the post-filter setting
T2,0	Remove post filter
T2,1	Set the post filter TC to 0.1 S
T2,2	Set the post filter TC to 1.0 S
V	Return the value of the SRQ mask
Vn	Set the SRQ Mask to the value n (See the Status Byte definition)
W	Return the RS232 wait interval
Wn	Set RS232 wait interval to nX4mS
Xn	Return the voltage at the rear panel analog port n. (n from 1 to 6)
X5,v	Set analog port 5 to voltage v
X6,v	Set analog port 6 to voltage v
Y	Return the Status Byte value
Yn	Test bit n of the Status Byte
Z	Reset to default settings and cancel all pending commands.

Status Byte Definition

Bit	Meaning
0	Magnitude too small to calculate phase
1	Command Parameter is out-of-range
2	No detectable reference input
3	PLL is not locked to the reference
4	Signal Overload
5	Auto-offset failed: signal too large
6	SRQ generated
7	Unrecognized or illegal command

Configuration Switches

There are two banks of 8 switches, SW1 and SW2, located on the rear panel. SW1 sets the GPIB address and SW2 sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately.

SW1:GPIB Mode Switches

Bit	Example	Function
1 }	up	GPIB Address Switches
2 }	up	Address 0 to 30 allowed
3 }	up	'up' for bit = 1
4 }	down	'down' for bit = 0
5 }	up	(Most Significant Bit)
6	down	'down' to echo on RS232 (normally 'up')
7	up	Not Used
8	up	Not Used

If the GPIB mode switches are set as shown in the example column above, then the lockin will be addressed as GPIB device #23, and all GPIB commands and data will be echoed over the RS232 for de-bugging purposes.

SW2:RS232 Mode Switches

Bit 1	Bit 2	Bit 3	Baud Rate
up	up	up	19200
down	up	up	9600
up	down	up	4800
down	down	up	2400
up	up	down	1200
down	up	down	600
up	down	down	300

Bit	Setting	Explanation
4	up	Odd parity
	down	Even parity
5	up	No parity
	down	Parity enabled
6	up	No echo (for computer)
	down	Echo mode (for terminal)
7	up	Two stop bits
	down	One stop bit
8		unused

Eight data bits are always sent, regardless of the parity setting. The most significant bit is always zero.

Example: Bit 1 'down' and all others 'up' for RS232 communication at 9600 baud, no parity, two stop bits, and no echo or prompts by the SR530.

SR530 Guide to Operation
Front Panel

The front panel has been designed to be almost self explanatory. The effect of each keypress is usually reflected in the change of a nearby LED indicator or by a change in the quantity shown on a digital display. This discussion explains each section of the front panel, proceeding left to right.

Signal Inputs

There are three input connectors located in the **SIGNAL INPUT** section of the front panel. The rocker switch located above the **B** input selects the input mode, either single-ended, **A**, differential, **A-B**, or current, **I**.

The **A** and **B** inputs are voltage inputs with 100 MΩ, 25 pF input impedance. Their connector shields are isolated from the chassis ground by 10 Ω. These inputs are protected to 100V dc but the ac input should never exceed 10V peak. The maximum ac input before overload is 1V peak.

The **I** input is a current input with an input impedance of 1 KΩ to a virtual ground. The largest allowable dc current before overload is 1 μA. No current larger than 10 mA should ever be applied to this input. The conversion ratio is 10^6 V/A, thus, the full scale current sensitivities range from 100 fA to 500 nA with a max ac input before overload of 1 μA peak. You should use short cables when using the current input.

Signal Filters

There are three user selectable signal filters available; a line frequency notch, a 2X line frequency notch, and an auto-tracking bandpass. Each of the filters has a pair of indicator LED's and a function key located in the **SIGNAL FILTERS** section of the front panel. Pressing a key will toggle the status of the appropriate filter. The status of each filter is displayed as **IN**, filter active, or **OUT**, filter inactive.

The notch filters have a Q of 10 and a depth of at least 50 dB. Thus, the line frequency notch is 6 Hz wide and the 2X line notch has a width of 12 Hz. Both of these filters can increase the dynamic reserve up to 50 dB at the notch frequencies. The achievable reserve is limited by the maximum allowable signals at the inputs. The notch frequencies are set at the factory to either 50 Hz or 60 Hz. The user can adjust these frequencies. (See the Maintenance and Repair section for alignment details.) These filters precede the bandpass filter in the signal amplifier.

The bandpass filter has a Q of 5 and a 6 dB roll off in either direction. Thus, the pass band (between 70% pass points) is always equal to 1/5th of the center frequency. The center frequency is continually adjusted to be equal to the internal demodulator frequency. When the reference mode is f, the filter tracks the reference. When the mode is 2f, the filter frequency is twice the reference input frequency. The center frequency tracks as fast as the reference oscillator can slew and may be used during frequency scans. The bandpass filter adds up to 20 dB of dynamic reserve for noise signals outside the pass band, and increases the harmonic rejection by at least 13dB. (2nd harmonic attenuated by 13 dB, higher harmonics attenuated 6dB/octave more.) If not needed to improve the dynamic reserve or the harmonic rejection then the filter should be left **OUT**.

Sensitivity

The sensitivity is displayed as a value (1-500) and a scale (nV, μV, mV). When using the current input, which has a gain of 10^6 V/A, these scales read fA, pA, and nA. The two keys in the **SENSITIVITY** section move the sensitivity up and down. If either key is held down, the sensitivity will continue to change in the desired direction four times a second.

The full scale sensitivity can range from 100 nV to 500 mV. The sensitivity indication is not changed by the **EXPAND** function. The **EXPAND** function increases the output sensitivity (Volts out /volts in) as well as the resolution of the digital output display.

Not all dynamic reserves are available at all sensitivities. If the sensitivity is changed to a setting for which the dynamic reserve is not allowed, the dynamic reserve will change to the next setting which is allowed. Sensitivity takes precedence over the dynamic reserve. The sensitivity range of each dynamic reserve is shown below.

Dynamic Reserve	Sensitivity Range
LOW	1 μV through 500 mV
NORM	100 nV through 50 mV
HIGH	100 nV through 5 mV

Dynamic Reserve

The dynamic reserve (DR) is set using the keys in the **DYNAMIC RESERVE** section. The reserve is displayed by the three indicator LED's, **HIGH**, **NORM**, **LOW**. Only those dynamic reserve settings available for the sensitivity are allowed (see above table). For example, when the sensitivity is 500 mV, the DR will always be **LOW**.

The dynamic reserve and output stability of each setting are shown below.

Setting	Dynamic Reserve	Output Stability (ppm/°C)
LOW	20 dB	5
NORM	40 dB	50
HIGH	60 dB	500

Since a higher DR results in degraded output stability, you should use the lowest DR setting for which there is no overload indication. Note that using the Bandpass Filter provides about 20dB of additional DR and so allows you to operate with a lower DR setting.

Status

There are five STATUS LED's.

OVLD indicates a signal overload. This condition can occur when the signal is too large, the sensitivity is too high, the dynamic reserve is too low, the offset is on, the expand is on, the time constant is not large enough, or the ENBW is too large.

The **OVLD** LED blinks four times a second when an output is overloaded. This occurs if an output exceeds full scale. For example, during a quadrature measurement where X exceeds full scale while Y is near zero, a blinking **OVLD** indicates that it is safe to take data from the Y output since only the X output is overloaded. The signal path to the Y output is not overloaded. **OVLD** also blinks if a noise measurement is attempted on an output which exceeds full scale.

If the **OVLD** LED is on continuously or flashes randomly, then an overload has occured before the output, i.e. in the ac amplifier or output time constant. In this case, the dynamic reserve, sensitivity, time constant, or ENBW needs to be adjusted.

UNLK indicates that the reference oscillator is not phase locked to the external reference input. This can occur if the reference amplitude is too low, the frequency is out of range, or the trigger mode is incorrect for the reference signal waveform.

ERR flashes when an error occurrs on one of the computer interfaces, such as an incorrect command, invalid parameter, etc.

ACT indicates activity on the computer interfaces. This LED blinks every time a character is received or transmitted by the SR530.

REM indicates that the unit is in the remote state and that the front panel controls are not operative. There are two remote states. The Remote-With-Lockout will not allow any inputs from the front panel. The Remote-Without-Lockout command allows you to return the front panel to operation by pressing the **LOCAL** key.

Display Select

The keys in the **DISPLAY** section select the parameters to be displayed on the **OUTPUT METERS** and the output of the two **OUTPUT BNC** connectors. The displayed parameters are indicated by one of the six **DISPLAY LED**'s and can be either the two demodulator outputs (**X Y**), the demodulator output offsets (**X OFST Y OFST**), the magnitude and phase (**R Ø**), the magnitude offset and phase (**R OFST Ø**), the rms noise on X and Y (**X NOISE Y NOISE**), or the D/A outputs (**X5 D/A X6**). When displaying **NOISE**, the equivalent noise bandwidth is selected in the **TIME CONSTANT** section. When displaying **D/A**, the 2 outputs are the **X5** and **X6** rear panel D/A outputs, allowing the D/A outputs to be set from the front panel. This feature can be used to set the reference frequency when using the internal oscillator.

Channel 1 Display

The channel 1 outputs are summarized below. X is equal to RcosØ where Ø is the phase shift of the signal relative to the reference oscillator of the lock-in.

display setting	CH1 output	expand?	offset?	X (RCOSØ)
X	$X+X_{ofst}$	yes	yes	$X+X_{ofst}$
X OFST	X_{ofst}	yes	yes	X_{ofst}
R	$R+R_{ofst}$	yes	yes	$X+X_{ofst}$
R OFST	R_{ofst}	yes	yes	$X+X_{ofst}$
XNOISE	X noise	yes	yes	$X+X_{ofst}$(enbw)
X5	X5	no	adjust	$X+X_{ofst}$

The **EXPAND** and **OFFSET** conditions for each display are retained when the **DISPLAY** is changed. Thus, when the **DISPLAY** is changed from **X** to **R**, the **EXPAND** and **OFFSET** assume the conditions set the last time the **DISPLAY** was **R**. If the **DISPLAY** is changed back to **X**, the **EXPAND** and **OFFSET** return to conditions set for **X**.

R Output

The magnitude, R, is given by the equation:

$$R = \{(X+X_{ofst})^2 + (Y+Y_{ofst})^2\}^{1/2} + R_{ofst}$$

Note that the X and Y offsets affect the value of R while the X and Y expands do not.

The magnitude output has a resolution of 12 bits plus sign and is updated every 3.5 mS. To achieve maximum accuracy, the magnitude should be as large a fraction of full scale as possible.

R is expanded after the calculation. Thus, when R is expanded, the full scale resolution drops by a factor of 10 to about 9 bits.

Output Channel 1

The **CHANNEL 1** output is available at the left hand **OUTPUT BNC** connector. The output parameter is selected by the **DISPLAY** setting and can be **X**, **X OFST**, **R** (magnitude), **R OFST**, **X NOISE**, or **X5** (external D/A). (Note that **X5** is the ratio output at power up. When displaying **X5**, the ratio output is 10R/X1). All outputs are ±10V full scale when the **EXPAND** is off. With the **EXPAND** on, the output is multipled by 10 effectively increasing the full scale sensitivity by 10. (**X5** may not be expanded). The output impedance is < 1 Ω and the output current is limited to 20 mA.

The left hand analog meter always displays the **CHANNEL 1 OUTPUT** voltage. Accuracy is 2% of full scale.

The **CHANNEL 1 LCD** display provides a read-out of the displayed parameter in real units. The scale of the displayed quantity is indicated by the three scale LED's to the left of the display. This read-out auto ranges and will reflect the sensitivity added when the **EXPAND** function is on. When displaying **X5**, the scale LED's are off and the units are volts.

Rel Channel 1

Every time the **REL** key is pressed, the displayed parameter is offset to zero. This is done by loading the displayed parameter's offset with minus one times the present output. If the output is greater than 1.024 times full scale, the **REL** function will not be able to zero the output. In this case, the **OFFSET ON** LED will blink and the offset value will be set to its maximum value.

The **REL** function and the manual **OFFSET** are both ways to enter the offset value. After using the **REL** key, the offset may be adjusted using the manual **OFFSET**.

When the **DISPLAY** is **X**, **X OFST**, or **X NOISE**, the **REL** key sets the X OFFSET (which affects the **X (RCOSØ)** output). If **X NOISE** is being displayed, the **REL** function zeroes **X** and the noise output will require a few seconds to settle again.

When the **DISPLAY** is **R** or **R OFST**, the **REL** key sets the R OFFSET.

The **REL** key zeroes the **X5** output when the **DISPLAY** is **D/A**.

Offset Channel 1

The **OFFSET** buttons control the manual offset. The offset is turned **ON** and **OFF** using the upper key in the **OFFSET** section. When the offset is **ON**, the lower two keys are used to set the amount of offset. A single key press will advance the offset by 0.025% of full scale. If the key is held down, the offset advances in larger and larger increments, the largest increment being 10% of full scale. When the offset is turned **OFF** the applied offset returns to zero but the offset value is not lost. The next press of the upper offset key (return to **ON**) sets the offset to the previously entered value.

If an attempt is made to advance the offset value beyond full scale, the **ON** LED will blink. An offset up to 1.024 times the full scale sensitivity may be entered. When the **EXPAND** is on, this is 10X the full scale output.

Note that the offsets (either manual offset or those generated by the **REL** function) represent a fraction of the full scale reading, and so their absolute value will change when the sensitivity scale is changed. A signal which has been nulled by an offset will not be nulled when the sensitivity scale is changed. The analog meter and the

output BNC indicate the same value given by the equation:

$V_{out} = 10A_e(A_vV_i\cos\emptyset+V_{os})$ (if the output is X)

where...

A_e = 1 or 10 per the Expand
A_v = 1/Sensitivity
V_i = magnitude of the signal
$\emptyset$ = phase between signal & reference
V_{os} = offset (fraction of FS < 1.024)

When the **DISPLAY** is **X**, **X OFST**, or **X NOISE**, the **OFFSET** keys adjust the X OFFSET (which affects the **X (RCOSØ)** output). When the **DISPLAY** is **R** or **R OFST**, the **OFFSET** keys adjust the R OFFSET. When the **DISPLAY** is **X5**, the **OFFSET** up and down keys set the output voltage of D/A output **X5** (also on the rear panel) up to ±10.24 V. Adjusting **X 5** will cancel the **RATIO** output.

Expand Channel 1

The output **EXPAND** is toggled by pressing the key in the Channel 1 **EXPAND** section. The expand status is indicated by the **X10**, expand on, and the **X1**, expand off, LED's. Only the Channel 1 **OUTPUT** is affected, the **X (RCOSØ)** output is not expanded.

The **X5** D/A output may not be expanded.

X (RCOSØ) Output

The analog output, $X+X_{ofst}$, is available at the **X (RCOSØ)** BNC connector. An input signal equal in magnitude to the selected sensitivity which is in phase with the reference oscillator will generate a 10V output. The output impedance is <1 Ω and the output current is limited to 20 mA.

The **X (RCOSØ)** output is affected by the X offset but may not be expanded. The **X (RCOSØ)** is not affected by the **DISPLAY** setting except for two cases. When the **DISPLAY** is set to **X OFST**, the **X (RCOSØ)** output is the X offset. When the **DISPLAY** is set to **X NOISE**, the **X (RCOSØ)** output has a bandwidth equal to the ENBW (1 or 10 Hz) instead of the time constant.

Channel 2 Display

The channel 2 outputs are summarized below. Y is equal to RsinØ where Ø is the phase shift of the signal relative to the reference oscillator of the lock-in.

display setting	CH2 output	expand?	offset?	Y (RSINØ)
Y	$Y+Y_{ofst}$	yes	yes	$Y+Y_{ofst}$
Y OFST	Y_{ofst}	yes	yes	Y_{ofst}
Ø	Phase	no	no	$Y+Y_{ofst}$
Ø	Phase	no	no	$Y+Y_{ofst}$
Y NOISE	Y noise	yes	yes	$Y+Y_{ofst}$(enbw)
X6	X6	no	adjust	$Y+Y_{ofst}$

The **EXPAND** and **OFFSET** conditions for each display are retained when the **DISPLAY** is changed. Thus, when the **DISPLAY** is changed from **Y** to **Ø**, the **EXPAND** and **OFFSET** turn off. If the **DISPLAY** is changed back to **Y** the **EXPAND** and **OFFSET** return to conditions set for **Y**.

Ø Output

The phase, Ø, is given by the equation:

$$\emptyset = -\tan^{-1}\{(Y+Y_{ofst})/(X+X_{ofst})\}$$

Note that the X and Y offsets affect the value of Ø while the X and Y expands do not.

The Phase Output voltage is 50 mV per degree with a resolution of 2.5 mV or 1/20 of a degree. The output range is from -180 to +180 degrees. The phase output is updated every 3.5 mS. To achieve maximum accuracy, the magnitude, R, should be as large a fraction of full scale as possible. If R is less than 0.5% of full scale, the phase output defaults to zero degrees.

The Phase Output may not be expanded and the **OFFSET** keys do not offset the Phase Output. However, the Phase Output can be offset using the Reference Phase shift.

The Reference Phase shift, which may be adjusted via the phase controls in the reference section, rotates the lock-in's internal coordinate axes relative to the reference input. The Phase Output is the phase difference between the signal and the lock-in's coordinate system. For example, if a signal exactly in phase with the reference input is being measured and the Reference Phase shift is zero, the Phase Output will be zero also. This is

because the lock-in coordinate system is in phase with the reference input and signal. If the Reference Phase shift is set to +45 degrees, then the lock-in coordinate system rotates to +45 degrees from the reference input. Thus, the reference input is now at -45 degrees from the lock-in coordinate axes. Since the reference and signal are in phase, the signal is now at -45 degrees with respect to the lock-in coordinates and the Phase Output will be -45 degrees.

The sum of the Reference Phase shift and the Phase Output is the absolute phase difference between the signal and the reference input. Therefore, the Phase Output may be offset to zero by adjusting the Reference Phase shift. This is sometimes necessary when the Phase Output is near 180 degrees and varies between +180 and -180 degrees.

Output Channel 2

The **CHANNEL 2** output is available at the right hand **OUTPUT BNC** connector. The output parameter is selected by the **DISPLAY** setting and can be **Y**, **Y OFST**, **Ø** (phase), **Ø** (phase), **Y NOISE**, or **X6** (ext D/A). All outputs are ±10V full scale when the **EXPAND** is off. With the **EXPAND** on, the output is multipled by 10, effectively increasing the full scale sensitivity by 10. (**Ø** and **X6** may not be expanded). The **Ø** (phase) output is 50 mV/deg (20 deg per Volt) up to ±9 V (±180 deg). The output impedance is <1 Ω and the output current is limited to 20 mA.

The right hand analog meter always displays the **CHANNEL 2 OUTPUT** voltage. Accuracy is 2% of full scale.

The CHANNEL 2 LCD display provides a read-out of the displayed parameter in real units. The scale of the displayed quantity is indicated by the four scale LED's to the right of the display. This read-out auto ranges and will reflect the sensitivity added when the **EXPAND** function is on. When displaying **X6**, the scale LED's are off and the units are volts.

Rel Channel 2

Every time the **REL** key is pressed, the displayed parameter is offset to zero. This is done by loading the displayed parameter's offset with minus one times the present output. If the output is greater than 1.024 times full scale, the **REL** function will not be able to zero the output. In this case, the **OFFSET ON** LED will blink and the offset value will be set to its maximum value.

The **REL** function and the manual **OFFSET** are both ways to enter the offset value. After using the **REL** key, the offset may be adjusted using the manual **OFFSET**.

When the **DISPLAY** is **Y**, **Y OFST**, or **Y NOISE**, the **REL** key sets the Y OFFSET (which affects the **Y (RSINØ)** output). If **Y NOISE** is being displayed, the **REL** function zeroes **Y** and the noise output will require a few seconds to settle again.

The **REL** key zeroes the **X6** output when the **DISPLAY** is **D/A**.

Auto Phase

When the **DISPLAY** is **Ø** (phase), the **REL** key sets the Reference Phase Shift to the absolute phase difference between the signal and the reference. This is done by setting the Reference Phase Shift to the sum of the Reference Phase Shift and the present Phase Output. After auto-phase is performed, the Ø output will be 0 deg, R will be unchanged, X will be maximized, and Y will be minimized.

Offset Channel 2

The **OFFSET** section controls the manual offset. The offset is turned **ON** and **OFF** using the upper key in the **OFFSET** section. When the offset is **ON**, the lower two keys are used to set the amount of offset. A single key press will advance the offset by 0.025% of full scale. If the key is held down, the offset advances in larger and larger increments, the largest increment being 10% of full scale. When the offset is turned **OFF** the applied offset returns to zero but the offset value is not lost. The next press of the upper offset key (return to **ON**) sets the offset to the previously entered value.

If an attempt is made to advance the offset value beyond full scale, the **ON** LED will blink. An offset up to 1.024 times the full scale sensitivity may be entered. When the **EXPAND** is on, this is 10X the full scale output.

Note that the offsets (either manual offset or those generated by the **REL** function) represent a fraction of the full scale reading, and so their absolute value will change when the sensitivity scale is changed. A signal which has been nulled by an offset will not be nulled when the sensitivity scale is changed. The analog meter and the output BNC indicate the same value given by the equation:

$V_{out} = 10A_e(A_vV_i\sin\emptyset+V_{os})$ {if the output is Y}

where...

A_e = 1 or 10 per the Expand
A_v = 1/Sensitivity
V_i = magnitude of the signal
$\emptyset$ = phase between signal & reference
V_{os} = offset (fraction of FS < 1.024)

When the **DISPLAY** is **Y**, **Y OFST**, or **Y NOISE**, the **OFFSET** keys adjust the Y OFFSET (which affects the **Y (RSINØ)** output). When the **DISPLAY** is **Ø**, the **OFFSET** keys do nothing. When the **DISPLAY** is **X6**, the **OFFSET** up and down keys set the output voltage of D/A output **X6** (also on the rear panel) up to ±10.24V.

Expand Channel 2

The output **EXPAND** is toggled by pressing the key in the Channel 2 **EXPAND** section. The expand status is indicated by the **X10**, expand on, and the **X1**, expand off, LED's. Only the Channel 2 **OUTPUT** is affected, the **Y (RSINØ)** output is not expanded. **Ø** and **X6** may not be expanded.

Y (RSINØ) Output

The analog output, $Y+Y_{ofst}$, is available at the **Y (RSINØ)** BNC connector. An input signal equal in magnitude to the selected sensitivity which is 90° out of phase with the reference oscillator will generate a 10V output. The output impedance is <1 Ω and the output current is limited to 20 mA.

The **Y (RSINØ)** output is affected by the Y offset but may not be expanded. The **Y (RSINØ)** is not affected by the **DISPLAY** setting except for two cases. When the **DISPLAY** is set to **Y OFST**, the **Y (RSINØ)** output is the Y offset. When the **DISPLAY** is set to **Y NOISE**, the **Y (RSINØ)** output has a bandwidth equal to the ENBW (1 or 10 Hz) instead of the time constant.

Reference Input

The **REFERENCE INPUT** BNC is located in **REFERENCE INPUT** section. The input is ac coupled and the impedance is 1 MΩ. The dc voltage at this input should not exceed 100 V and the largest ac signal should be less than 10 V peak.

Trigger Level

The **TRIGGER MODE** indicator toggles from **POSITIVE** to **SYMMETRIC** to **NEGATIVE** when the **TRIGGER MODE** key is pressed.

If the center **TRIGGER MODE** LED is on, the mode is **SYMMETRIC** and the reference oscillator will lock to the positive zero crossings of the ac reference input. The ac signal must be symmetric (e.g. sine wave, square wave, etc.) and have a peak to peak amplitude greater than 100 mV. A signal with 1 Vrms amplitude is recommended. The phase accuracy of the reference channel is specified for a 1Vrms sinewave in the symmetric trigger mode.

If the upper **TRIGGER MODE** LED is on, the mode is **POSITIVE**. The trigger threshold is +1V and the reference oscillator will lock to the positive going transitions of the reference input. This mode triggers on the rising edges of a TTL type pulse train. The pulse width must be greater than 1 µS.

If the lower **TRIGGER MODE** LED is on, the mode is **NEGATIVE**. The trigger threshold is -1V and the reference oscillator will lock to the negative going transitions of the reference input. This mode triggers on a negative pulse train or on the falling edges of a TTL type pulse train (remembering that the input is ac coupled). The pulse width must be greater than 1 µS.

Reference Mode

The **REFERENCE MODE** indicator toggles between **f** and **2f** whenever the **MODE** key is pressed. When the **MODE** is **f**, the lock-in will detect signals at the reference input frequency. When the **MODE** is **2f**, the lock-in detects signals at twice the reference input frequency. In either case, the reference oscillator has a maximum frequency of 100 KHz, thus, when in the **2f** mode, the reference input frequency may not exceed 50 KHz.

Reference Display

The **REFERENCE DIGITAL DISPLAY** shows either the reference oscillator frequency or phase shift. The displayed parameter toggles between the two whenever the **SELECT** key is pressed. The appropriate scale indicator below the display will be on. It is useful to check the frequency display to verify that the lock-in has correctly locked to your reference. The reference frequency is measured to 1 part in 256 resolution at all frequencies. The display reads .000 if there is no

reference input and 199.9 kHz if the input frequency exceeds 105 kHz.

Phase Controls

The phase shift between the reference oscillator of the lock-in and the reference input signal is set using the four keys in the **PHASE** section. The two keys below the **FINE** label increment the phase setting in small amounts. A single key press will change the phase by 0.025 degrees in the desired direction. Holding the key down will continue to change the phase with larger and larger steps with the largest step being 10 degrees. The two **90°** keys are used to change the phase by 90 degree increments. The upper key will add 90 degrees and the lower key will subtract 90 degrees. Holding both keys down at once sets the phase shift back to zero. The **REFERENCE DIGITAL DISPLAY** automatically displays the phase whenever any of the **PHASE** keys are pressed. The phase ranges from -180 degrees to +180 degrees and is the phase delay from the reference input signal.

Time Constant

There are two post demodulator low pass filters, labeled **PRE** and **POST**. The **PRE** filter precedes the **POST** filter in the output amplifier. Each filter provides 6 dB/oct attenuation.

The **PRE** filter time constant ranges from **1 mS** to **100 S** and is selected by the two keys below the **PRE** filter indicator LED's. Holding down either key will advance the time constant four times a second in the desired direction.

In many servo applications, no time constant is needed. The SR530 may be modified to reduce the output time constant to about 20 µS. Contact the factory for details.

The **POST** filter time constant can be set to **1 S** or **0.1 S**, or can be removed altogether, **NONE**, using the two keys below the **ENBW** indicators. When set to **NONE**, the total attenuation is that of the **PRE** filter, or 6 dB/oct. When the **POST** filter is **1 S** or **0.1S**, the total attenuation is 12 dB/oct for frequency components beyond the larger of the **POST** and **PRE** filter bandwidths (reciprocal time constant).

Noise

When the **DISPLAY** is set to **X NOISE Y NOISE**, none of the **PRE** and **POST** indicator LED's are on. Instead, one of the two **ENBW** indicators will be on, showing the Equivalent Noise Bandwidth of the rms noise calculation. The **ENBW** is set using the keys below the **ENBW** indicator LED's (same keys as used to set the **POST** filter). The **PRE** filter keys do nothing in this case. Pressing the upper key when the bandwidth is already **1 Hz** will reset the rms noise average (output) to zero, restarting the calculation. Likewise with pressing the lower key when **10 Hz** is already selected.

The noise is the rms deviation of the output within a 1 or 10 Hz equivalent noise bandwidth about the reference frequency. A dc output does not contribute to the noise, the noise is determined only by the ac 'wiggles' at the output. By measuring the noise at different frequencies, the frequency dependence of the noise density can be found. This usually has the form of $v_{noise} \sim 1/f$.

The noise computation assumes that the noise has a Gaussian distribution (such as Johnson noise). Since the computation takes many time constants (reciprocal ENBW), the noise output should be allowed to approach a steady value before a reading is taken. For the 1 Hz ENBW, this time is on the order of 15 to 30 seconds; for the 10 Hz ENBW, the output stabilizes much faster. The noise output will vary slightly since there will always be noise variations that are slow compared to the bandwidth. Any DC component in the output will not contribute to the noise. However, a large DC output will cause the noise computation to initially rise to a large value before approaching the final answer. As a result, the computation will take longer to settle.

If the **OVLD** indicator is blinking four times a second, then either the X or Y output is overloaded and the corresponding noise calculation should be ignored. If the **OVLD** LED is on continuously, then the input signal is overloading the ac amplifier or time constant filters. In this case, both noise outputs will be wrong

To obtain a value for the noise density, the noise reading should be divided by the square root of the ENBW. Thus, when the ENBW is 1 Hz, the noise output is the noise density, and when the ENBW is 10 Hz, the noise density is the noise output divided by √10. For example, if the input noise is measured to be 7 nV with the ENBW set to 1 Hz, the noise density is 7 nV/√Hz. Switching the ENBW to 10 Hz results in a faster measurement and a reading of 22 nV on the output. The noise density is 22 nV/√10 Hz or 7 nV/√Hz. At frequencies » 10 Hz, the noise density should be independent of the ENBW.

Power

This is the instrument's **POWER** switch. When the power is turned off, the front panel settings are retained so that the instrument will return to the same settings when the power is next turned on. The SR530 always powers up in the **LOCAL** mode.

The D/A outputs **X5** and **X6** are not retained during power off. **X5** always becomes the **RATIO** output at power on and **X6** is always reset to zero.

When the power is turned on, the **CHANNEL 1 OUTPUT DIGITAL DISPLAY** will show the **SERIAL NUMBER** of the instrument and the **CHANNEL 2 OUTPUT DIGITAL DISPLAY** will show the firmware **VERSION**. The **REFERENCE DIGITIAL DISPLAY** shows the model number of the instrument. All displays return to normal after 3 seconds.

Local and Remote

When the instrument is programmed via the computer interface to be in the **REMOTE** state **WITHOUT LOCK-OUT**, the **LOCAL** key will return the instrument to **LOCAL** front panel control. If the instrument is in the **REMOTE WITH LOCK-OUT** state, no front panel key will return the status to **LOCAL**. In this case, a **RETURN TO LOCAL** command must be sent over the computer interface or the power must be turned off and back on.

Defaults

If the **LOCAL** key is held down when the **POWER** is turned on, the instrument settings will be set to the defaults shown below instead of the settings in effect when the power was turned off.

Parameter	Setting
BANDPASS	OUT
LINE	OUT
LINE X 2	OUT
SENSITIVITY	500 mV
DYN RES	LOW
DISPLAYS	X Y
EXPANDS	OFF
OFFSETS	OFF (value=0)
PRE TIME CONSTANT	100 mS
POST TIME CONSTANT	0.1 S
ENBW	1 Hz
REFERENCE MODE	f
TRIGGER MODE	SYMMETRIC
REFERENCE DISPLAY	FREQUENCY
PHASE SHIFT	0°

Whenever default values are used at power up, the red **ERR** LED will turn on for about 3 seconds. If the **ERR** LED is on when the instrument is powered on without the **LOCAL** key down, then the instrument is ignoring the retained settings. This can be due to a low battery.

SR530 Guide to Operation
Rear Panel

AC Power

The ac line voltage selector card, line fuse, and line cord receptacle are located in the fuse holder at the left side of the rear panel. See the section, **Preparation for Use** at the front of this manual for instructions on setting the ac voltage selector and choosing the correct fuse.

GPIB Connector

The SR530 has an IEEE 488 (GPIB) interface built in. The GPIB address is set using **SW1** located to the right of the interface connectors. Refer to page 7 for switch setting details.

RS232 Connector

The SR530 has an RS232 interface. The connector is configured as a **DCE**. The baud rate, parity, stop bits, and echo mode are selected using **SW2** located to the right of the interface connectors. Refer to Page 7 for switch setting details.

Signal Monitor Output

This BNC provides the buffered output of the signal amplifiers and filters. This is the signal just before the demodulator. The output impedance is <1 Ω. When a full scale input is applied, the peak-to-peak amplitude at this output is 20 mV, 200 mV or 2 V for dynamic reserve settings of high, norm, and low, respectively.

Preamp Connector

This 9 pin "D" connector provides power and control signals to external peripherals such as pre-amplifiers. The available power is described below.

Pin	Voltage	Current Available
1	+20	100 mA
2	+5	10 mA
6	-20	100 mA
7	Signal ground	
8	Digital ground	

General Purpose A/D and D/A

There are four analog input ports, labeled **X1** through **X4**. These inputs may be digitized and read via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 2.5 mV. The input impedance is 1 MΩ. A digitization can be performed in about 3 mS but the result may take longer to transmit over the interface being used.

There are two analog output ports, labeled **X5** and **X6**. The voltages at these ports may be programmed via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 2.5 mV. The output impedance is <1 Ω and the output current is limited to 20 mA.

Ratio

Output **X5** is the ratio output when not programmed by the computer interface or set via the front panel. **X5** becomes the ratio output whenever the unit is turned on.

The voltage at **X5** is the ratio of the Channel 1 Output to the analog voltage at port **X1**. An output of 10 V corresponds to a ratio of 1. The ratio is computed by digitizing the Channel 1 Output and the voltage at port **X1** and then taking the ratio. The resolution is 2.5 mV. For best accuracy, the sensitivity should be set to provide at least a 50% full scale signal and the analog denominator (**X1**) should be 5V or greater. The ratio is updated approximately every 3 mS. For the Ratio feature to work, the voltage at the denominator input must exceed 40 mV.

When the **DISPLAY** is set to **D/A**, the ratio output is 10 times the magnitude, **R**, divided by **X1**.

Internal Oscillator

The **INTERNAL OSCILLATOR** is a voltage controlled oscillator with a sine wave output . To use the oscillator as the reference source, connect the **REF OUTPUT** on the rear panel to the **REF INPUT** on the front panel. The **REF OUTPUT** is a 1 Vrms sine wave. The **SINE OUTPUT** may be used as the stimulus to the experiment. The **SINE OUTPUT** can be set to three amplitudes, 1 V, 100 mV, and 10 mV (rms) using the

amplitude switch. The output impedance is 600 Ω. The **AMP CAL** screw adjusts the amplitude.

The oscillator frequency is controlled by the **VCO INPUT** voltage. A voltage from 0V to 10V will adjust the frequency according to the **VCO RANGE** selected. Three ranges are available, 1 Hz/V, 100 Hz/V, and 10 KHz/V. The input impedance is 10 kΩ. The **FREQUENCY CAL** screw adjusts the frequency.

There are four ways to set the frequency:

1) Connect **X5** or **X6** (D/A outputs) to the **VCO INPUT**. The frequency can now be set from the front panel by setting the **DISPLAY** to **D/A** and adjusting **X5** or **X6**. The frequency is also controllable via the computer interfaces by programming **X5** or **X6**.

2) If the **VCO INPUT** is left open, then the oscillator will run at the top of its range (i.e. 10 Hz, 1 KHz, or 100 KHz).

3) A 10 KΩ potentiometer may be connected from the **VCO INPUT** to ground. This pot will then set the frequency.

4) Connect the VCO INPUT to an external voltage source which can provide 0 to 10V.

In all four cases, if the **REF OUTPUT** is connected to the **REFERENCE INPUT** on the front panel, the frequency may be read on the front panel **REFERENCE DIGITAL DISPLAY** or via the computer interfaces.

SR530 Guide to Programming

The SR530 Lock-in Amplifier is remotely programmable via both RS232 and GPIB interfaces. It may be used with laboratory computers or simply with a terminal. All front panel features (except signal input selection and power) may be controlled and read via the computer interfaces. The SR530 can also read the analog outputs of other laboratory instruments using its four general purpose analog input ports. There are also two programmable analog output ports available to provide general purpose control voltages.

Communicating with the SR530

Before using either the RS232 or GPIB interface, the appropriate configuration switches need to be set. There are two banks of 8 switches, **SW1** and **SW2**, located on the rear panel. **SW1** sets the GPIB address and **SW2** sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately. For details on switch settings, see page 7 at the front of this manual.

Command Syntax

Communications with the SR530 use ASCII characters. Commands to the SR530 may be in either UPPER or lower case.

A command to the SR530 consists of one or two command letters, arguments or parameters if necessary, and an ASCII carriage return (<cr>) or line-feed (<lf>) or both. The different parts of the command do not need to be separated by spaces. If spaces are included, they will be ignored. If more than one parameter is required by a command, the parameters must be separated by a comma. Examples of commands are:

G 5 <cr>	set the sensitivity to 200 nV
T 1,4 <cr>	set the pre filter to 30 mS
F <cr>	read the reference frequency
P 45.10 <cr>	set phase shift to 45.10°
X 5,-1.23E-1 <cr>	set port X5 to -0.123 V

Multiple commands may be sent on a single line. The commands must be separated by a semicolon (;) character. The commands will not be executed until the terminating carriage return is sent.

An example of a multiple command is:

G 5; T 1,4; P 45.10 <cr>

It is not necessary to wait between commands. The SR530 has a command input buffer of 256 characters and processes the commands in the order received. Likewise, the SR530 has an output buffer (for each interface) of 256 characters.

In general, if a command is sent without parameters, it is interpreted as a request to read the status of the associated function or setting. Values returned by the SR530 are sent as a string of ASCII characters terminated usually by carriage return, line-feed. For example, after the above command is sent, the following read commands would generate the responses shown below.

Command	Response from the SR530
G <cr>	5<cr><lf>
T 1 <cr>	4<cr><lf>
P <cr>	45.10<cr><lf>

The choice of terminating characters sent by the SR530 is determined by which interface is being used and whether the 'echo' feature is in use. The terminating sequence for the GPIB interface is always <cr><lf> (with EOI). The default sequence for RS232 is <cr> when the echo mode is off, and <cr><lf> when the echo mode is on. The terminating sequence for the RS232 interface may be changed using the J command.

Note that the terminating characters are sent with each value returned by the SR530. Thus, the response to the command string G;T1;P<cr> while using the RS232 non-echo mode would be 5<cr>4<cr>45.10<cr>.

Front Panel Status LED's

The **ACT** LED flashes whenever the SR530 is sending or receiving characters over the computer interfaces.

The **ERR** LED flashes whenever an error has occurred, such as, an illegal command has been received, a parameter is out of range, or a communication buffer has exceeded 240 characters. This LED flashes for about three seconds on power-up if the battery voltage is insufficient to retain previous instrument settings.

The **REM** LED is on whenever the SR530 is programmed to be in the remote state.

RS232 Echo and No Echo Operation

In order to allow the SR530 to be operated from a terminal, an echo feature has been included which

causes the unit to echo back commands received over the RS232 port. This feature is enabled by setting switch 6 on **SW2** to the DOWN position. In this mode, the SR530 will send line-feeds in addition to carriage returns with each value returned and will also send the prompts 'OK>' and '?>' to indicate that the previous command line was either processed or contained an error. Operating the SR530 from a terminal is an ideal way to learn the commands and responses before attempting to program a computer to control the SR530. When the unit is controlled by a computer, the echo feature should be turned off to prevent the sending of spurious characters which the computer is not expecting.

Try-Out with an ASCII Terminal

Before attempting any detailed programming with the SR530, it is best to try out the commands using a terminal. Connect a terminal with an RS232 port to the RS232 connector on the rear panel of the SR530. A 'straight' RS232 cable is required since the SR530 is a DCE and the terminal is a DTE. Set the baud rate, parity, and stop bits to match the terminal by setting **SW2** per the switch setting table given on page 7. The echo mode should be enabled (switch 6 DOWN). After setting **SW2** and connecting the terminal, hold down the **LOCAL** key while turning the unit on. This causes the SR530 to assume its default settings so that the following discussion will agree with the actual responses of the SR530. The **ACT** and **ERR** LED's on the front panel will flash for a second and the sign-on message will appear on the terminal. Following the message, the prompt 'OK>' will be displayed. This indicates that the SR530 is ready to accept commands.

Type the letter 'P' followed by a carriage return (P<cr>). The SR530 responds by sending to the terminal the characters 0.00 indicating that the phase is set to 0 degrees. In general, a command with no arguments or parameters reads a setting of the unit. To set the phase to 45 degrees, type the command, P45<cr>. To see that the phase did change, use the **SELECT** key on the front panel to display the phase on the **REFERENCE DIGITAL DISPLAY**. Typing the phase read command, P<cr>, will now return the string 45.00 to the terminal.

Now read the gain using the sensitivity read command, G<cr>. The response should be 24 meaning that the sensitivity is at the 24th setting or 500 mV. Change the sensitivity by typing G19<cr>. The sensitivity should now be 10 mV. Check the front panel to make sure this is so.

The Channel 1 Output of the lock-in is read by typing the command, Q1<cr>. The response is a signed floating point number with up to 5 significant digits plus a signed exponent. Change the gain to 10 uV using the G10 command. The response to the Q1 command will now be similar to the previous one except that the exponent is different.

Attach a DC voltmeter to the **X6** output on the rear panel. The range should allow for 10V readings. The voltage at the **X6** output can be set using the **X6** command. Type X6,5.0<cr> and the **X6** output will change to 5.0V. To read this back to the terminal, just type **X6**<cr>. When setting the **X6** voltage, the voltage may be sent as an integer (5), real (5.000), or floating point (0.500E1) number. Now connect the **X6** output to the **X1** input (also on the rear panel). **X1** through **X4** are analog input ports. To read the voltage on **X1**, simply type X1<cr>. The response 5.000 should appear on the terminal. The analog ports **X1** through **X6** can be used by your computer to read outputs of other instruments as well as to control other laboratory parameters.

At this point, the user should experiment with a few of the commands. A detailed command list follows.

SR530 Command List

The leading letters in each command sequence specify the command. The rest of the sequence consists of parameters. Multiple parameters are separated by a comma. Those parameters shown in {} are optional while those without {} are required. The variables m and n represent integers while v represents a real number. Parameters m and n must be expressed in integer format while v may be in integer, real, or floating point format.

A X
A Y
A R
A P

The A command causes the **auto offset (rel)** function to execute. Auto offset is performed by reading the output and using that value as the appropriate offset. Every time an "AX" command is received, the auto offset function is executed on the X output. The "AY" command auto offsets the Y output. The "AR" command auto offsets the R output. Note that "AX" and "AY" will affect the R output but "AR" will not affect X and Y. The "AP" command will execute the auto-phase routine. This is done by setting the reference phase shift with the present phase difference between the signal and the reference input. The Ø output then reads zero and the reference display reads the signal phase shift. "AP" maximizes X and minimizes Y but R is unaffected. The A commands may be issued at any time, regardless of the DISPLAY setting.

B {n}

If n is "1", the B command sets the **bandpass** filter in. If n is "0", the bandpass filter is taken out. If n is absent, then the bandpass filter status is returned.

C {n}

If n is "1", the C command sets the **reference LCD display** to show the phase setting. If n is "0", the LCD will display the reference frequency. If n is absent, the parameter being displayed (frequency or phase) is returned. Note that the P and F commands are used to read the actual values of the phase and frequency.

D {n}

If n is included, the D command sets the **dynamic reserve**. If n is absent, the dynamic reserve setting is returned.

n	Dyn Res
0	LOW
1	NORM
2	HIGH

Note that not all dynamic reserve settings are allowed at every sensitivity.

E m {,n}

The E command sets and reads the status of the output **expands**. If m is "1", then Channel 1 is selected, if m is "2", Channel 2 is selected. The parameter m is required. If n is "1", the E command expands the selected output channel. If n is "0", the expand is turned off for the selected channel. If n is absent, the expand status of the selected channel is returned. Note that the expands do not affect the X and Y BNC outputs, only the Channel 1 and 2 outputs.

F

The F command reads the reference **frequency**. For example, if the reference frequency is 100 Hz, the F command returns the string "100.0". If the reference frequency is 100.0 kHz, the string "100.0E+3" is returned. The F command is a read only command.

G {n}

If n is included, the G command sets the **gain** (sensitivity). If n is absent, the gain setting is returned.

n	Sensitivity	
1	10	nV
2	20	nV
3	50	nV
4	100	nV
5	200	nV
6	500	nV
7	1	µV
8	2	µV
9	5	µV
10	10	µV
11	20	µV
12	50	µV
13	100	µV
14	200	µV
15	500	µV
16	1	mV
17	2	mV
18	5	mV
19	10	mV
20	20	mV
21	50	mV
22	100	mV
23	200	mV
24	500	mV

Note that sensitivity settings below 100 nV are allowed only when a pre-amplifier is connected.

H
The H command reads the **pre-amplifier status**. If a pre-amplifier is connected, a "1" is returned, otherwise, a "0" is returned. The H command is a read only command.

I {n}
If n is included, the I command sets the **remote-local** status. If n is absent, the remote-local status is returned.

n	Status
0	Local: all front panel keys are operative
1	Remote: front panel keys are not operative. The **LOCAL** key returns the status to local.
2	Lock-out: front panel keys are not operative. No key returns the status to local. Another I command is needed to return to local.

When using the GPIB interface, the REN, LLO, and GTL commands are not implemented. The I command is used by both interfaces to set the remote-local status.

J {n1,n2,n3,n4}
The J command sets the RS232 **end-of-record** characters sent by the SR530 to those specified by the decimal ASCII codes n1-n4. If no argument is included, the end-of-record sequence returns to the default (a carriage return), otherwise, up to four characters may be specified. The end-of-record required by the SR530 when receiving commands is not affected.

K n
The K command simulates a front panel **key press**. The effect is exactly the same as pressing the selected key once. The parameter n is required.

n	Key
1	Post Time Constant Up
2	Post Time Constant Down
3	Pre Time Constant Up
4	Pre Time Constant Down
5	Select Display (f/phase)
6	90 ° Up
7	90 ° Down
8	Zero Phase (Simultaneous 90 ° Up and Down)
9	Reference Trigger Mode
10	Reference Mode (f/2f)
11	Degrees Up
12	Degrees Down
13	Channel 2 Rel
14	Channel 2 Offset (On/Off)
15	Channel 2 Offset Up
16	Channel 2 Offset Down
17	Channel 2 Expand
18	Output Display Up
19	Output Display Down
20	Channel 1 Expand
21	Channel 1 Rel
22	Channel 1 Offset (On/Off)
23	Channel 1 Offset Up
24	Channel 1 Offset Down
25	Dyn Res Up
26	Dyn Res Down
27	Sensitivity Up
28	Sensitivity Down
29	Local
30	Line X 2 Notch Filter
31	Line Notch Filter
32	Bandpass Filter

L m {,n}
The L command sets and reads the status of the line **notch filters**. If m is "1", then the 1X line notch is selected, if m is "2", the 2X line notch is selected. The parameter m is required. If n is "1", the L command sets the selected filter in. If n is "0", the selected filter is taken out. If n is absent, the status of the selected filter is returned.

M {n}
If n is "1", the M command sets the **reference mode** to 2f. If n is "0", the reference mode is set to f. If n is absent, the reference mode is returned.

N {m}
If m is "1", the N command sets the **ENBW** to 10 Hz. If m is "0", the ENBW is set to 1 Hz. If m is absent, the ENBW setting is returned.

OX {n} {,v}
OY {n} {,v}
OR {n} {,v}
The "OX", "OY", and "OR" commands set the **offsets** for the X, Y, and R outputs respectively. If n is "1", the offset is turned on. If n is "0", the offset is turned off. If n and v are absent, the offset status (on or off) is returned. (The value of the offset is read using the S and Q commands.) If n is included, then v may be sent also. v is the offset value up to plus or minus full scale in units of volts. For example, to offset half of full scale on the 100 µV sensitivity, v should be "50.0E-6" or an equivalent value. However, if the sensitivity is then changed to 200 µV, the offset is now half of the new full scale or 100 µV. When the sensitivity is changed, the offset is preserved as a constant fraction of full scale rather than as a voltage

referred to the input. The expand function will, on the other hand, preserve the value of the offset as an input referred voltage. Once a value of v is sent, the offsets may be turned off and on without losing the offset values by using the O commands without the v parameter. Note that the X and Y offsets will affect the R output but the R offset does not affect the X or Y output.

P {v}
If v is absent, the P command returns the **reference phase shift** setting from -180 to +180 degrees. When v is included, the phase is set to the value of v up to ±999 degrees.

Q 1
Q 2
Q X
Q Y
The Q commands return the **output** values in units of volts or degrees. For an input signal of 50 µV on a full scale sensitivity of 100 µV, a Q command will return the string "50.00E-6". "Q1" and "Q2" read the parameters being shown on the Channel 1 and Channel 2 output displays as selected with the S command. "QX" and "QY" read the X (RCOSØ) and Y (RSINØ) BNC outputs.

R {n}
If n is included, the R command sets the **reference input trigger** mode. If n is absent, the trigger mode is returned.

n	Mode
0	Positive
1	Symmetric
2	Negative

S {n}
If n is included, the S command selects the parameters shown on the Channel 1 and 2 analog meters, output digital displays, and output BNC's. If n is absent, the displayed parameter is returned.

n	Channel 1	Channel 2
0	X	Y
1	X Offset	Y Offset
2	R	Ø
3	R Offset	Ø
4	X Noise	Y Noise
5	X5 (D/A)	X6 (D/A)

T m {,n}
The T command sets and reads the status of the **time constants**. If m is "1", the pre time constant is selected, if m is "2", the post time constant is selected. The parameter m is required. If n is included, the T command sets the selected time constant. If n is absent, the setting of the selected time constant is returned.

n	Pre Time Constant (m=1)
1	1 mS
2	3 mS
3	10 mS
4	30 mS
5	100 mS
6	300 mS
7	1 S
8	3 S
9	10 S
10	30 S
11	100 S

n	Post Time Constant (m=2)
0	none
1	0.1 S
2	1 S

U m {,n}
The U command sets and reads the unit's **calibration** bytes. m is the address offset of the byte, 0-511. If n is absent, the value of the addressed calibration byte is returned. If n is included, the addressed calibration byte is set to the value of n, 0-255. The new value will be in effect until the power is turned off or a reset command is issued. Use of this command is not recommended.

V {n}
If n is included, the V command sets the GPIB **SRQ** (service request) mask to the value n (0-255). If n is absent, the value of the SRQ mask is returned.

W {n}
The W command sets and reads the RS232 character **wait** interval. If n is included, the SR530 will wait nx4 mS between characters sent over the RS232 interface. This allows slow computer interfaces to keep up. n can range from 0 to 255. If n is absent, the wait value is returned. The wait interval is set to 6 on power-up.

X n {,v}
n designates one of the 6 general purpose **analog ports** located on the rear panel. If n is 1,2,3, or 4, the X command will return the voltage on the designated analog input port (X1-X4) in volts. If n is 5 or 6, then v may also be sent. If v is included, the designated analog output port (X5 or X6) will be set to v volts where v has the range -10.238V to +10.238V. If v is absent, the output value of the selected port is returned. On power-up, port X5 is the ratio output. An "X 5" command will read the ratio output. An "X 5" command with the parameter v will set port X5 to v volts, overriding

the ratio output. Port X5 will return to the ratio output on power-up or reset.

Y {n}
The Y command reads the **status** byte. (See the following section for a definition of the Status Byte.) n designates one bit, 0-7, of the status byte. If n is included, the designated bit of the status byte is returned. The bit which is read is then reset. If n is absent, the value of the entire byte is returned and all status bits are then reset. This status byte may also be read over the GPIB using the serial poll command.

Z
The Z command causes an internal **reset**. All settings return to the default values shown on page 15. The **ERR** LED will be on for about three seconds to indicate that the stored instrument settings are being ignored. If the RS232 echo mode is on, the sign-on message is sent over the RS232 interface.

Status Byte

The SR530 maintains an 8-bit status register which the user may read to obtain information on the unit's status. The status byte may be read in two ways: by sending the Y command, which returns the value of the byte in ASCII coded decimal, or, when using the GPIB, by performing a serial poll. The returned status byte reflects all of the status conditions which have occurred since the last time the byte was read. After the status byte has been read, it is cleared. Thus, the status byte should be read initially to clear all previous conditions (especially after a power up or after settings have been changed).

The definitions for each bit of the status byte are given below:

Bit 0
Phase Output Defaulted to Zero. When this bit is set, it indicates that the magnitude of the signal (R) fell below 0.4% of full scale, causing the phase output to default to zero.

Bit 1
Command Parameter Out of Range. This bit is set if a parameter associated with a command is not in the allowed range.

Bit 2
No Reference. This bit is set when no reference input is detected, either because the amplitude is too low or the frequency is out of range.

Bit 3
Unlock. This bit is set when the reference oscillator is not locked to the reference input. If there is no reference input, bit 2 (no reference) will be set but bit 3 (unlock) may not be.

Bit 4
Overload. This bit is set if there is a signal overload. This can happen when the sensitivity is too high, the dynamic reserve is too low, the offset is on, or the expand is on. Overloads on the general purpose A/D inputs or the ratio output are not detected.

Bit 5
Auto Offset Out of Range. This bit is set if the auto offset function cannot zero the output because the output exceeded 1.024X full scale.

Bit 6
SRQ. This bit is set if the SR530 has generated an SRQ on the GPIB interface. This bit is reset after the SR530 has been serial polled. This bit is set only for status reads via a serial poll, ie., Bit 6 always zero for the RS232 .

Bit 7
Command Error. This bit is set when an illegal command string is received.

Errors

Whenever a 'parameter out of range' or an 'unrecognized command' error occurs, the appropriate status bits are set and the **ERR** LED flashes. In addition, any commands remaining on the current command line (up to the next <cr>) are lost. The **ERR** LED will also light if any of the internal communication buffers overflows. This occurs when 240 characters are pending on the command queue or output queue. The **ERR** LED will go off as soon as all buffers drop below 200 characters again.

Reset

The Z command resets the unit to its default state. The default front panel settings are listed in the **DEFAULTS** section of the **Guide to Operations**. In addition, the interface status returns to LOCAL, the SRQ mask is cleared, the RS232 character WAIT interval is set to 6, and the terminating sequence is reset to the proper defaults.

The command and output buffers are cleared by the Z command. Therefore, it is bad practice to use the Z command before all previous commands

have been processed and all responses have been received.

Trouble-Shooting Interface Problems

If you are having difficulty getting your computer to communicate with the SR530 look to the sections on the RS232 and GPIB interfaces for some tips specific to your particular interface.

An ASCII terminal is a valuable aid for debugging interface problems. You can use it to:

1) become familiar with the SR530's command structure,

2) see GPIB bus transactions by using the GPIB echo mode,

3) eavesdrop on transactions when using the RS232 interface,

4) substitute a human for the SR530 by using a null modem cable (to make the DTE a DCE) and attaching the terminal to the port to which you would normally have connected the SR530. This allows you to test your program's responses to inputs which you provide from the terminal.

Common Hardware Problems include:

1) The RS232 or GPIB cables are not properly attached.

2) The configuration switches for the RS232 characteristics or GPIB address are not set correctly (Make sure the RS232 echo is off when using the RS232 interface with a computer. The GPIB with RS232 echo mode should be off when not debugging the GPIB interface.)

3) Your computer requires an RS232 control line to be asserted, but your cable does not pass it between the SR530 and the computer, or, your computer is not asserting the DTR line on the RS232 .

Common Software Problems include:

1) You have sent the wrong command to ask for data from the SR530. Your program will wait forever for a response which is not going to come. This may not be your fault; we have seen Microsoft's Interpreted Basic on the IBM PC occasionally send a curly bracket (ASCII 253) when it was supposed to have sent a carriage return (ASCII 13).

2) Your computer's baud rate has been changed and no longer matches the SR530's baud rate.

3) The initial command sent to the SR530 was invalid due to a garbage character left in the command queue from power-up, or, the first character in you computer's UART is garbage, also due to power-up. It is good practice to send a few carriage returns to the SR530 when your program begins, and have your program clear-out its UART at the start of your program.

4) The SR530 is not sending the correct 'end-of-record' marker for your computer. For example, it appears that Microsoft's Rev 3.2 FORTRAN on the IBM PC under DOS 2.1 requires two carriage returns for an end-of-record marker. The J command can be used to set the SR530 end-of-record marker to 2 carriage returns. [The end-of-record marker is that sequence which indicates that the response is complete. From the keyboard, a single carriage return is the end-of-record marker.]

5) Answers are coming back from the SR530 too fast, overwriting the end-of-record markers, and causing the computer to hang waiting for a complete response. In this case, the W command can be used to slow down the response time of the SR530 preventing overwriting.

6) Answers are coming back from the SR530 too slowly due to the W6 default setting for the character interval time. Use the W command to speed up the transmission from the SR530. This can cause problems for the GPIB interface if the echo mode is on (switch 6 of SW1).

The SR530 with the RS232 Interface

The RS232 is a popular serial interface standard for bit serial communication. Despite the existence of the standard there are many permutations of control lines, baud rates, and data formats. If you do not have a lot of experience interfacing RS232 equipment you should read Appendix B for a description of the RS232 and interfacing tips.

Data Communications Equipment (DCE)

The SR530 is configured as DCE so that it may be connected directly to a terminal. If the SR530 is to be interfaced with another DCE device, a special cable (sometimes referred to as a 'modem' cable) is required. To use the RS232 interface you must set the switches in **SW2** to match your computer's baud rate, parity, and number of stop bits. Refer to Page 7 for details.

Wait Command

The SR530 normally waits until the RS232 'Clear to Send' control line (CTS) is asserted before sending characters. However, some computers do not set and reset the CTS line, possibly causing the SR530 to send data when the computer is not ready to read it. The SR530 may be 'slowed down' using the W command. Sending 'Wn' causes the unit to wait nx4 mS before sending each character over the RS232 bus. The command W0 sets the wait interval to zero and results in the fastest transmission. The wait interval is set to 6 (24 mS)on power-up.

Termination Sequences

The default RS232 termination characters are sufficient to interface with most computers, however, it will occasionally be necessary to send special terminating sequences to fit the requirements of some computers. This can be done with the J command. The format for the command is:

J {n1,n2,n3,n4}

where n1, n2, n3, and n4 are decimal values between 0 and 255 corresponding to the ASCII codes of the desired termination characters. For instance, if the desired termination sequence is an asterisk, (ASCII 42), two carriage returns, (ASCII 13), and a line-feed, (ASCII 10), the appropriate command is:

J 42,13,13,10

If a G command is sent requiring an answer of 24 (sensitivity = 500 mV), the SR530 would respond with the string

24*<cr><cr><lf>

Up to four terminating characters may be specified by the J command. If no arguments are sent with the J command, the terminating sequence returns to the default (echo on: <cr><lf>; echo off: <cr>).

The J command does not affect the terminating character (<cr>) required at the end of commands received by the SR530. It also does not affect the terminating sequence sent with data over the GPIB interface.

The SR530 with the GPIB Interface

For a brief introduction to the GPIB standard, please read Appendix C at the back of this manual. Before using the GPIB interface you must set the switches in **SW1** per the instructions on page 7.

GPIB Capabilities

The GPIB capabilities of the SR530 consistent with IEEE standard 488 (1978) are shown in the table below. Also shown are the responses of the SR530 to some standard commands.

Code	Function
SH1	Source handshake capability
AH1	Acceptor handshake capability
T5	Basic Talker, Serial Poll, Unaddressed to talk if addressed to listen
L4	Basic Listener, Unaddressed to listen if addressed to talk
SR1	Service request capability
PP0	No parallel poll capability
DC1	Device Clear capability
RL0	REN,LLO, GTL not implemented. 'I' command sets Remote-Local.

SR530 Response to GPIB Commands

Mnemonic	Command	Response
DCL	Device Clear	Same as Z command
SDC	Selected Device Clear	Same as Z command
SPE	Serial Poll Enable	Send Status Byte, & clear status byte

Because the SR530 can be controlled by an RS232 interface as well as the GPIB, the remote-local functions are not standard. There is no local with lock out state. When in the local state, remote commands are processed, even without the REN command being issued. This is because the RS232 interface has no provision for bus commands and remote commands over the RS232 interface would never be enabled.

Serial Polls and Service Requests

The status byte sent by the SR530 when it is serial polled is the same status byte which is read

using the Y command (except for bit 6, SRQ). Of course, when the SR530 is serial polled, it does not encode the status byte as a decimal number. The SR530 can be programmed to generate a service request (SRQ) to the GPIB controller every time a given status condition occurs. This is done using the V{n} command. The mask byte, n (0-255), is the SRQ mask byte. The mask byte is always logically ANDED with the status byte. If the result is non-zero, the SR530 generates an SRQ and leaves the status byte unchanged until the controller performs a serial poll to determine the cause of the service request. When the unit has been serial polled, the status byte is reset to reflect all of the status conditions which have occurred since the SRQ was generated.

For example, if we want to generate an SRQ whenever there is an overload or unlock condition, we need an SRQ mask byte equal to 00011000 binary, or 24 decimal ("V24" command). The byte 00011000 binary corresponds to the status byte with the 'no reference' and 'unlock' status bits set. If an overload occurs, then an SRQ will be generated. The serial poll will return a status byte showing SRQ and overload. If an unlock condition occurs before the serial poll is concluded, another SRQ will be generated as soon as the serial poll is finished. A second serial poll will reflect the unlock condition.

Any SRQ generated by the 'no reference, 'unlock', 'overload', and 'auto over-range' conditions will also reset the corresponding bit in the SRQ mask byte. This is to prevent a constant error condition (such as no reference applied to the input) from continually interrupting the controller. When such an SRQ occurs, the controller should change some parameter so as to solve the problem, and then re-enable the SRQ mask bit again using the V command.

GPIB with RS232 Echo Mode

It is sometimes useful when debugging a GPIB system to have some way of monitoring exactly what is going back and forth over the bus. The SR530 has the capability to echo all characters sent and received over the GPIB to its RS232 port. This mode of operation is enabled by setting switch 6 of **SW1** to the DOWN position. The baud rate, stop bits, and parity of the RS232 port are still set by **SW2**. Of course, the RS232 port operates at much lower speeds than the GPIB and will slow down the GPIB data rate in this mode. (Use the W0 command to allow the RS232 interface to run at full speed, otherwise, the GPIB transactions may take so long that the controller can hang.) During actual use, this mode should be disabled.

The SR530 with BOTH Interfaces

If both interfaces are connected, commands may be received from either interface. Responses are always sent to the source of the request (except in GPIB echo mode). It is unwise to send commands from the two interfaces at the same time since the characters from different sources can become interleaved on the command queue and result in 'unrecognized command' errors.

The Lock-in Technique

The Lock-in technique is used to detect and measure very small ac signals. A Lock-in amplifier can make accurate measurements of small signals even when the signals are obscured by noise sources which may be a thousand times larger. Essentially, a lock-in is a filter with an arbitrarily narrow bandwidth which is tuned to the frequency of the signal. Such a filter will reject most unwanted noise to allow the signal to be measured. A typical lock-in application may require a center frequency of 10 KHz and a bandwidth of 0.01 Hz. This 'filter' has a Q of 10^6 - well beyond the capabilities of passive electronic filters.

In addition to filtering, a lock-in also provides gain. For example, a 10 nanovolt signal can be amplified to produce a 10 V output--a gain of one billion.

All lock-in measurements share a few basic principles. The technique requires that the experiment be excited at a fixed frequency in a relatively quiet part of the noise spectrum. The lock-in then detects the response from the experiment in a very narrow bandwidth at the excitation frequency.

Applications include low level light detection, Hall probe and strain gauge measurement, micro-ohm meters, C-V testing in semiconductor research, electron spin and nuclear magnetic resonance studies, as well as a host of other situations which require the detection of small ac signals.

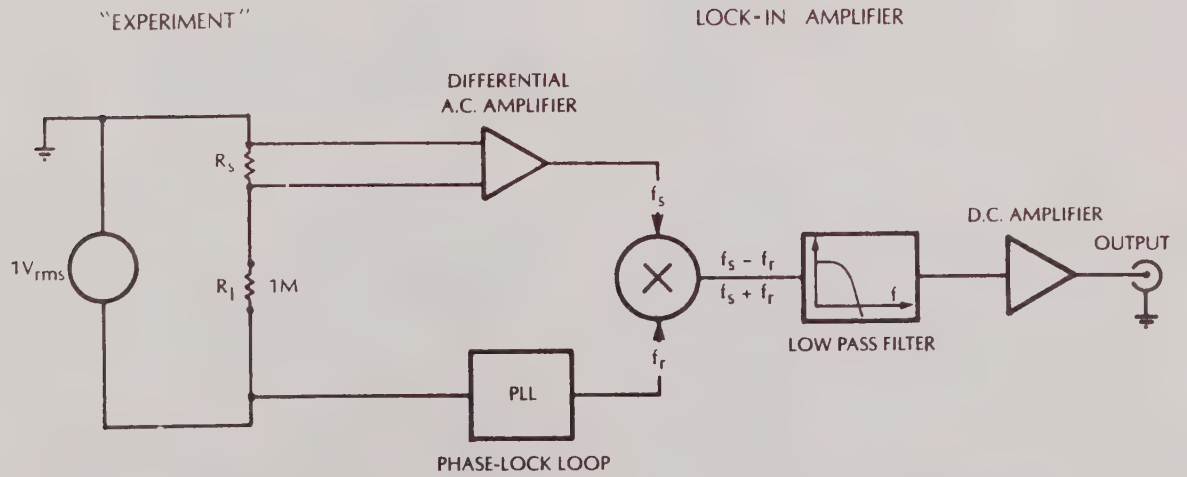
A Measurement Example

Suppose we wish to measure the resistance of a material, and we have the restriction that we must not dissipate very much power in the sample. If the resistance is about 0.1 Ω and the current is restricted to 1 μA, then we would expect a 100 nV signal from the resistor. There are many noise signals which would obscure this small signal -- 60Hz noise could easily be 1000 times larger, and dc potentials from dissimilar metal junctions could be larger still.

In the block diagram shown below we use a 1Vrms sine wave generator at a frequency w_r as our reference source. This source is current limited by the 1 MΩ resistor to provide a 1 μA ac excitation to our 0.1 Ω sample.

Two signals are provided to the lock-in. The 1V ac reference is used to tell the lock-in the exact frequency of the signal of interest. The lock-in's Phase-Lock Loop (PLL) circuits will track this input signal frequency without any adjustment by the user. The PLL has two outputs, $\cos(w_r t)$ and $\sin(w_r t)$.

The signal, $V_s \cos(w_s t+\emptyset)$, from the sample under test is amplified by a high gain ac coupled differential amplifier. The output of this amplifier is multiplied by the PLL outputs in two Phase-Sensitive Detectors (PSD1 and PSD2). This multiplication shifts each frequency component of



the input signal, w_s, by the reference frequency, w_r, so that the output of the PSD's are given by:

$$V_{psd1} = V_s \cos(w_r t) \cos(w_s t+\Ø)$$

$$= 1/2\ V_s \cos[(w_r + w_s)t+\Ø] + 1/2\ V_s \cos[(w_r - w_s)t+\Ø]$$

$$V_{psd2} = V_s \sin(w_r t) \cos(w_s t+\Ø)$$

$$= 1/2\ V_s \sin[(w_r + w_s)t+\Ø] + 1/2\ V_s \sin[(w_r - w_s)t+\Ø]$$

The sum frequency component of each PSD is attenuated by a low pass filter, and only those difference frequency components within the low pass filter's narrow bandwidth will pass through to the dc amplifiers. Since the low pass filter can have time constants up to 100 seconds, the lock-in can reject noise which is more than .0025 Hz away from the reference frequency input.

For signals which are in phase with the reference ($\Ø=0°$), the output of PSD1 will be a maximum and the output of PSD2 will be zero. If the phase is non-zero, $V_{psd1} \sim \cos(\Ø)$ and $V_{psd2} \sim \sin(\Ø)$. The magnitude output is given by,

$$R = \{(V_{psd1})^2 + (V_{psd2})^2\}^{1/2} \sim V_s$$

and is independent of the phase Ø. The phase output is defined as

$$\Ø = \tan^{-1}(V_{psd2}/V_{psd1})$$

Thus, a dual-phase lock-in can measure the amplitude of the signal, independent of the phase, as well as measure an unknown phase shift between the signal and the reference.

Understanding the Specifications

The table below lists some specifications for the SR530 lock-in amplifier. Also listed are the error contributions due to each of these items. The specifications will allow a measurement with a 2% accuracy to be made in one minute.

We have chosen a reference frequency of 5 kHz so as to be in a relatively quiet part of the noise spectrum. This frequency is high enough to avoid low frequency '1/f' noise as well as line noise. The frequency is low enough to avoid phase shifts and amplitude errors due to the RC time constant of the source impedance and the cable capacitance.

The full-scale sensitivity of 100 nV matches the expected signal from our sample. The sensitivity is calibrated to 1%. The instrument's output stability also affects the measurement accuracy. For the required dynamic reserve, the output stability is 0.1%/°C. For a 10°C temperature change we can expect a 1% error.

A front-end noise of 7 nV/√Hz will manifest itself as a 1.2 nVrms noise after a 10 second low-pass filter since the equivalent noise bandwidth of a single pole filter is 1/4RC. The output will converge exponentially to the final value with a 10 second time constant. If we wait 50 seconds, the output will have come to within 0.7% of its final value.

The dynamic reserve of 60 dB is required by our expectation that the noise will be a thousand times larger than the signal. Additional dynamic reserve is available by using the bandpass and notch filters.

A phase-shift error of the PLL tracking circuits will cause a measurement error equal to the cosine of the phase shift error. The SR530's 1° phase accuracy will not make a significant contribution to the measurement error.

Specifications for the Example Measurement

Specification	Value	Error
Full Scale Sensitivity	100 nV	
Dynamic Reserve	60 dB	
Reference Frequency	5 kHz	
Gain Accuracy	1%	1%
Output Stability	0.1%/°C	1%
Front-End Noise	< 7 nV/√Hz	1.2%
Output Time Constant	> 10 S	0.7%
Total RMS Error		2%

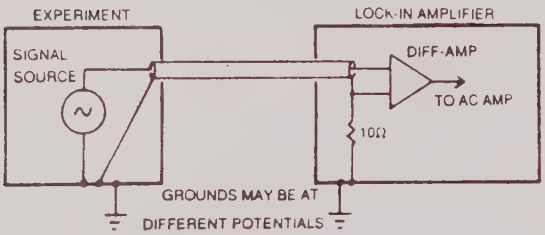
Shielding and Ground Loops

In order to achieve the 2% accuracy given in this measurement example, we will have to be careful to minimize the various noise sources which can be found in the laboratory. (See Appendix A for a brief discussion on noise sources and shielding) While intrinsic noise (Johnson noise, 1/f noise and alike) is not a problem in this measurement, other noise sources could be a problem. These noise sources can be reduced by proper shielding.

There are two methods for connecting the lock-in to the experiment: the first method is more convenient, but the second eliminates spurious pick-up more effectively.

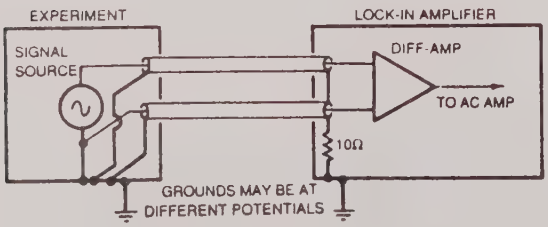
In the first method, the lock-in uses the A input in a 'quasi-differential' mode. Here, the lock-in detects

the signal as the voltage between the center and outer conductors of the A input. The lock-in does not force A's shield to ground, rather it is connected to the lock-in's ground via a 10Ω resistor. Because the lock-in must sense the shield voltage (in order to avoid the large ground loop noise between the experiment and the lock-in) any noise pickup on the shield will appear as noise to the lock-in. For a low impedance source (as is the case here) the noise picked up by the shield will also appear on the center conductor. This is good, because the lock-in's 100 dB CMRR will reject most of this common mode noise. However, not all of the noise can be rejected, especially the high frequency noise, and so the lock-in may overload on the high sensitivity ranges.



Quasi-Differential Connection

The second method of connecting the experiment to the lock-in is called the 'true-differential' mode. Here, the lock-in uses the difference between the center conductors of the A & B inputs as the input signal. Both of the signal sources are shielded from spurious pick-up.



True-Differential Connection

With either method, it is important to minimize both the common mode noise and the common mode signal. Notice that the signal source is held near ground potential in both cases. A signal which appears on both the A & B inputs will not be perfectly cancelled: the common mode rejection ratio (CMRR) specifies the degree of cancellation. For low frequencies the CMRR of 100 dB indicates that the common mode signal is canceled to 1 part in 10^5, but the CMRR decreases by about 6 dB/octave (20 dB/Decade) starting at 1KHz. Even with a CMRR of 10^5, a 10 mV common mode signal behaves like 100nV differential signal.

There are some additional considerations in deciding how to operate the lock-in amplifier:

Dynamic Reserve (DR) is the ratio of the largest noise signal that the lock-in can tolerate before overload to the full scale input. Dynamic reserve is usually expressed in dB. Thus a DR of 60 dB means that a noise source 1000 times larger than a full scale input can be present at the input without affecting the measurement of the signal. A higher DR results in a degraded output stability since most of the gain is DC gain after the phase sensitive detector. In general, the lowest DR which does not cause an overload should be used.

The Current Input has a 1 kΩ input impedance and a current gain of 10^6 Volts/Amp. Currents from 500 nA down to 100 fA full scale can be measured. The impedance of the signal source is the most important factor to consider in deciding between voltage and current measurements.

For high source impedances, (>1 MΩ), and small currents use the current input. Its relatively low impedance greatly reduces the amplitude and phase errors caused by the cable capacitance-source impedance time constant. The cable capacitance should still be kept small to minimize the high frequency noise gain of the current preamplifier.

For moderate source impedances, or larger currents, the voltage input is preferred. A small value resistor may be used to shunt the source. The lock-in then measures the voltage across this resistor. Select the resistor value to keep the source bias voltage small while providing enough signal for the lock-in to measure.

The Auto-Tracking Bandpass Filter has a Q of 5 and follows the reference frequency. The passband is therefore 1/5 of the reference frequency. The bandpass filter can provide an additional 20 dB of dynamic reserve for noise signals at frequencies outside the passband. The filter also improves the harmonic rejection of the lock-in. The second harmonic is attenuated an additional 13dB and higher harmonics are

attenuated by 6 dB/octave more. You may wish to use the bandpass filter and select a low dynamic reserve setting in order to achieve a better output stability. Since the processor can only set the bandpass filter's center frequency to within 1% of the reference frequency, this filter can contribute up to 5° of phase shift error and up to 5% of amplitude error when it is used. In addition, the bandpass filter adds a few nanovolts of noise to the front end of the instrument when it is in use.

Line Notch Filters should be used in most measurement situations. The filters will reject about 50 dB of line frequency noise (about a factor of 300). If your reference frequency is one octave away, then these filters will introduce a 10° phase shift error, and a few percent amplitude error. Their effect on your signal is negligible if your reference frequency is more than two octaves away.

The frequency range of the SR530 lock-in amplifier extends from 0.5Hz to 100KHz. No additional cards are required for the instrument to cover its full frequency range. The SR530 can be used to detect a signal at the reference frequency or at twice the reference frequency to allow for convenient measurement of the harmonic of the signal.

Output Filters can have one pole (6 dB per octave) or two poles (12 dB/octave). A two-pole filter provides a signal to noise improvement over a single-pole filter due to its steeper roll off and reduced noise bandwidth. Single-pole filters are preferred when the lock-in is used in a servo system to avoid oscillation.

In many servo applications, no output filtering is needed. In this case, the SR530 may be modified to reduce the output time constant to about 20 μS. Contact the factory for details.

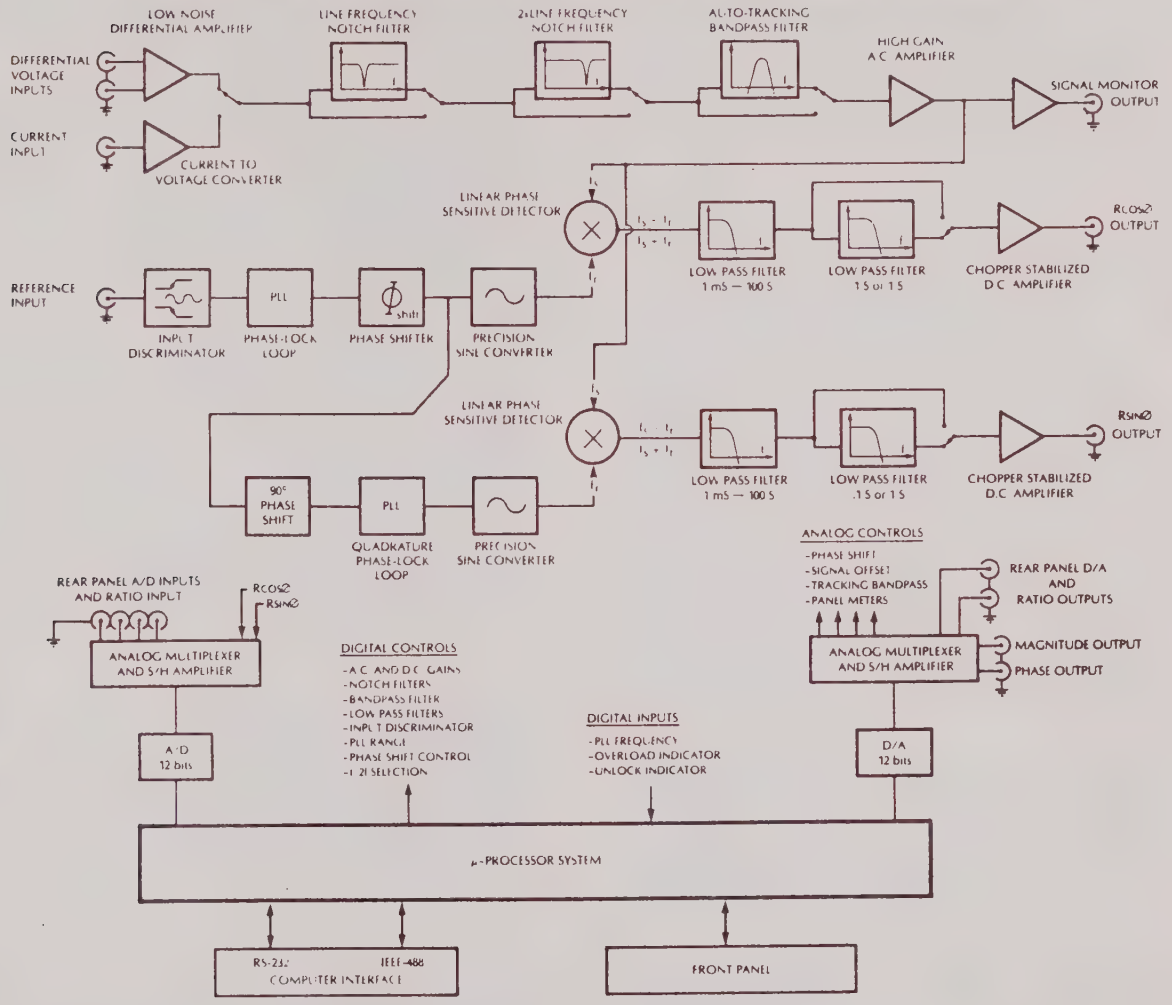
Noise measurement is a feature which allows direct measurement of the noise density of the signal at the reference frequency. This is a useful feature to assess at what frequency you should run your experiment.

Ratio Capability allows the lock-in's output to be divided by an external voltage input. This feature is important in servo applications to maintain a constant loop gain, and in experiments to normalize a signal to the excitation level.

Computer Interface allows a computer to control and to record data from the instrument. This is the single most important feature for extending the lock-in's capabilities and it's useful lifetime. Measurements which are impractical without a computer become simple when a computer is used to coordinate various parts of the experiment.

The Internal Oscillator provides a reference source for the lock-in. This allows the lock-in's frequency to be set without an additional signal generator. It also provides a sine wave to be used as the signal stimulus in an experiment. The frequency may be set via the computer interface as well as manually.

LOCK-IN AMPLIFIER DIAGRAM



SR530 Block Diagram

Several new concepts are used to simplify the design of SR530 lock-in amplifier. In addition to implementing recent advances in linear integrated circuit technology, the instrument was designed to take full advantage of its microprocessor controller to improve performance and to reduce cost.

As an example of the new techniques used in the SR530, consider the harmonic rejection problem. Previously, lock-in amplifiers used a PLL with a square wave output. The Fourier components of the square wave created a serious problem -- the lock-in would respond to signal and noise at f, 3f, 5f,.ad infinitum. Quite often, one component of this picket fence of frequencies would land on some noise source, giving a spurious result. To overcome this difficulty designers employed tuned amplifiers or heterodyning techniques. All of these 'fix-ups' had drawbacks, including phase and amplitude errors, susceptiblity to drift, and card-swapping to change frequencies.

In contrast, the SR530 detects the signal by mixing a reference sine wave in a precision analog multiplier. Because of the low harmonic content of this sine wave, the instrument is insensitive to harmonics. This approach has eliminated the difficulty, performance compromises, and cost of the older techniques.

The Signal Channel

The instrument has both current and voltage inputs. The current input is a virtual ground, and the 100 MΩ voltage inputs can be used as single-ended or true differential inputs.

There are three signal filters. Each of these filters may be switched 'in' or 'out' by the user. The first filter is a line notch filter. Set to either 50 or 60 Hz, this filter provides 50 dB of rejection at the line frequency. The second filter provides 50 dB of rejection at the first harmonic of the line frequency. The third filter is an auto-tracking bandpass filter with a center frequency tuned by the microprocessor to the frequency of the signal. These three filters eliminate most of the noise from the signal input before the signal is amplified.

A high-gain ac amplifier is used to amplify the signal before entering the phase sensitive detector. The high gain which is available from this programmable amplifier allows the lock-in to operate with a lower gain in its dc amplifier. This arrangement allows high stability operation even when used on the most sensitive ranges.

Reference Channel

The processor controlled reference input discriminator can lock the instrument's PLL to a variety of reference signals. The PLL can lock to sine waves or to logic pulses with virtually no phase error. The PLL outputs are phase shifted and shaped to provide two precision sine waves. The two sine waves have 90° of phase shift between them.

Phase Sensitive Detectors

The Phase Sensitive Detectors are linear multipliers which mix the amplified and filtered signal with the reference sine waves. The difference frequency component of the multipliers' outputs are dc signals that are proportional to the amplitude of the signal. The low-pass filters which follow each multiplier can reject any frequency components which are more than a fraction of a Hertz away from the signal frequency.

DC Amplifiers and System Gain

Dc amplifiers amplify and offset the outputs of the two low pass filters. The total system gain is the product of the ac and dc amplifier gains. The partitioning of the system gain between these ac and dc amplifiers will affect the stability and dynamic reserve of the instrument. The output is most stable when most of the gain is in the ac amplifier, however, high ac gain reduces the dynamic reserve.

For the most demanding applications, the user may specify how the system gain is partitioned. However, with prefilters that are able to provide up to 100 dB of dynamic reserve, and with chopper stabilized dc amplifiers, most users will not be concerned with just how the system gain is allocated.

A Microprocessor Based Design

The instrument was designed to take full advantage of its microprocessor controller. This approach provides several key advantages...

The instrument may be interfaced to a laboratory computer over the RS232 and IEEE-488 interfaces. In addition to simply reading data from the lock-in, the computer can control all of the instrument settings with simple ASCII commands.

A key feature of the instrument is its four A/D inputs and two D/A outputs. These analog I/O ports may be used to read and supply analog voltages to an experiment or measurement. All of the input and output ports have a full scale range of ±10.24Vdc with 2.5 mV resolution and 0.05% accuracy.

Computer control can eliminate set-up errors, reduce tedium, allow more complete data recording and post measurement analysis. Also, the computer can play an active role in the data acquisition by adjusting gains, etc., in response to changing measurement conditions.

The microprocessor based design eliminates many analog components to improve performance, reliability, and reduce cost. For example, the magnitude and phase outputs are calculated by the microprocessor instead of using an analog vector summer. This eliminates the temperature drifts and inaccuracies associated with nonlinear analog circuits and greatly reduces the number of parts. Each unit is computer calibrated at the factory, and calibration constants are placed in the instrument's read-only memory. The SR530 has only one-fifth of the analog trimming components that are found in older designs.

Circuit Description

Introduction

The SR530 Lock-in amplifier is an integrated instrument combining state of the art analog design with advanced microprocessor based control and interfaces. This discussion is intended to aid the advanced user in gaining a better understanding of the instrument.

The SR530 has eight main circuit areas: the signal amplifier, the reference oscillator, the demodulator, the analog output and controls, the front panel, the microprocessor, the computer interfaces, and the power supplies. With the exception of the front panel, the quadrature oscillator and demodulator, and a few pieces of hardware, the entire lock-in is built on a single printed circuit board. Each section is isolated from the others as much as possible to prevent spurious signal pickup. To aid in the location of individual components, the first digit (or first two digits of a four digit part number) of each part number generally refers to the schematic sheet number on which it occurs. To help find the part on the circuit board, the parts list includes a location on the circuit board for each component. Parts with a four digit part number beginning with 10,11, or 12 are found on the quadrature detector plug-in board located in the center of the main circuit board. Part numbers beginning with 6 refer to parts on the front panel.

Signal Amplifier

Assuming the input selector switch is set to a voltage input, the signal is coupled in through capacitors C101 and C102. The input impedance is set by the 100 MΩ resistors R101 and R102 over the operating frequency range. Note that R103 isolates the signal shields from the instrument ground forcing the return signal current back along the cable shields. The signal is then applied differentially to the gates of Q101. Q101 is a low noise dual JFET. The drain current through R109 is kept constant by 2/2 U101. The other half of U101 maintains a virtual null between the drains of the two transistors and thus an identical current flows through R110. Any input that would cause a differential between the two drains is amplified by 1/2 U101 and fed back via R112 in such a way as to reduce that differential. Since the two transistors are at equal and constant currents, their gate-source potentials are constant. Thus, the fed back signal which appears at the source of the right hand transistor exactly matches the input . Likewise, this signal will match the input to the left hand transistor but with the opposite sign. Resistors R112 and R110 attenuate the fed back signal from the output of U101 resulting in a differential input, single ended output, fixed gain of 10 amplifier. P101 adjusts the current balance between the two transistors and therefore their gain match and common mode rejection.

The output of the pre-amp is scaled by resistors R119-R122 and analog switch U103 which make up a 1-2-5-10 attenuator. The signal is then amplified by 2/2 U102. Input overload is sensed through diodes D101-D104.

Current Amplifier

When the input selector is set to current, the input to the pre-amp comes from the output of the current to voltage converter, 1/2 U102. U102 is a low voltage-noise bipolar op amp. Q102 serves as an input buffer to provide low current-noise to the input. The op amp always maintains a null at the gates of Q102 thus providing an input impedance of 1KΩ (R128). The input current is converted to a voltage by R135 and the op amp. Q103 bootstraps out the summing junction capacitance of Q102.

Notch Filters

U107 is a high Q, line frequency, notch filter which can be switched in and out by analog switch 1/4 U106. The frequency and depth of the filter can be adjusted with P102 and P103. Resistors R146-R149 and switch U108 make up a selectable attenuator. U118 is a line frequency 2nd harmonic notch filter selected by 2/4 U106. P104 and P105 adjust the frequency and depth. The second notch filter has a gain of 3 and its output is scaled by U110 and resistors R156-R159. The signal then takes two paths; to inverting amplifier U111 and to the input of the tracking bandpass filter. U111 has the same gain as the bandpass filter. The output of either U111 or the bandpass filter is selected by 3/4 U112 and 4/4 U106 and amplified by U113. U114 and U115 provide a last stage of gain and scaling and the final output is ac coupled and buffered by 4/4 U208.

Bandpass Filter

The bandpass filter is a three op amp state-variable active filter. 3/4 of U201 make up the three op amps of the standard filter. U203, U204, and U205 are analog switches which select the feedback capacitors for the 5 decades of operation. The two halves of U202 are matched transconductance amplifiers operating as programmable, voltage controlled, current sources which take the place of the normal, frequency setting, resistors. A voltage proportional to the

reference frequency is converted into a current by 1/4 U208 and Q201. This current programs the effective "resistance" of the two transconductance amplifiers and thus, tunes the center frequency of the filter to follow the reference. The output of the filter is buffered by 4/4 U201. The two remaining op amps in U208 are used to detect signal overloads throughout the amplifier chain.

Reference Oscillator

The reference input signal is ac coupled and buffered by U301. R378 isolates the reference shield from the lock-in ground to prevent ground loop currents. 1/2 U303 switches the polarity of the reference reaching comparator U304. U305 is a retriggerable one-shot whose output indicates a no reference condition if no comparator pulses are generated for three seconds.

U309 is a dual transconductance amplifier in a triangle VCO configuration. U310 selects the integrating capacitor depending on the frequency range. The VCO frequency is determined by the programming current through R318 and therefore by the output voltage of U308. C306 is the phase-locked loop low pass filter which is buffered by U308. U307 is a programmable current source used to charge and discharge C306. The amount of current available to U307 is determined by the VCO control voltage, thus, the tracking rate of the VCO is proportional to the VCO frequency. The triangle output is compared to a constant voltage by U314. 1/2 U313 and 1/2 U312 select f or 2f operation. This signal is fed back to the phase detector U306 to be compared with the reference output of U304. U315 compares the triangle output with a variable voltage to generate a square-wave signal phase-shifted from the reference. The range of this fine phase shift control is -5 to 95 degrees.

The output of U315 serves as the reference to a second phase-locked loop. This second PLL uses a similar proportional tracking triangle VCO. Comparator U329 looks at the square wave output of the VCO while comparator U328 detects the zero crossings of the triangle output. 1/2 U327 selects one these comparators to feed back to the phase detector, U316. Since the square and triangle outputs are in quadrature, U327 selects either an in-phase or quadrature relationship between the two VCO's. Thus, the output of the second VCO can be shifted from -5 to 185 deg from the reference.

The triangle output is divided by R363 and R362 before reaching transconductance amplifier 2/2 U322. The amplitude of the triangle input to this amplifier is enough to just saturate the input and provide a sine wave output. 2/2 U325 then amplifies the sine wave before it goes to the demodulator. U324 is a comparator which generates a square wave in-phase with the sine output. U326 divides the frequency of the square wave by eight and 2/2 U327 selects the frequency of the square wave chopper.

The square wave output of U322 serves as the reference to the quadrature oscillator PLL. This PLL is identical to the triangle oscillator, sine wave shaper described above. U1004 detects the zero-crossings of the triangle wave to feed back to the phase comparator, U1002. This ensures that the quadrature triangle wave is 90 deg out of phase from the first sine wave. The quadrature triangle is shaped into a sine wave by 2/2 U1009 and amplified by 2/2 U1014. U1012 is a comparator which generates a square wave in-phase with the quadrature sine wave. U1013 divides the frequency of the square wave by eight and 1/2 U1011 selects the frequency of the square wave chopper.

Demodulator and Low Pass Amplifier

Amplifier U402 and switch U401 select the polarity of the reference sine wave. This allows phase shifts up to 360 degrees from the reference input. The sine wave is ac coupled by U403 and inverted by U404. U405 selects alternating polarities of the sine wave at the chopper frequency, f/2 or f/16. This chopped sine wave is then multiplied by the output of the signal amplifiers by the analog multiplier U406. The synchronous output of the multiplier that corresponds to the in-phase signal is a square wave at the chopper frequency. The output is ac coupled by U407 to remove the dc offset of the multiplier. U408 inverts the signal and U405 chops the square wave to recover a dc output. U409 buffers the chopper output before the first low pass time constant. Op amps U416 and 2/2 U402 make up the first low pass amplifier with relays U411-U415 and U417 selecting the time constant. The second low pass amplifier is U419. Analog switch U418 selects the time constant and gain. The full scale output of U418 is 5 volts.

The quadrature demodulator and low pass amplifiers are identical to that described above. The quadrature detector output is provided by U1119.

Analog Output and Control

The dc output of the demodulator/low pass amplifiers is passed to the reference input of multiplying DAC U502. The DAC is programmed with the appropriate attenuation to calibrate the

overall gain of the lock-in. Every gain setting in each dynamic reserve is calibrated independently and the proper attenuations are stored in the unit's ROM.

The quadrature output is calibrated by DAC U1201. Amplifiers U1204 and U1205 buffer the two demodulator outputs to drive the X and Y BNC's.

A/D's

Analog multiplexer U504 selects the signal to be digitized by the microprocessor. This signal can be either the lock-in's in-phase or quadrature output or one of the four independent analog inputs buffered by U501. These general purpose inputs are located on the rear panel of the instrument. The selected signal is sampled and held on capacitor C502 and buffered by 4/4 U508. The A/D conversion is done by successive approximation using comparator U514 to compare the sampled and held signal with known outputs of U505, a 12 bit DAC with a precision reference. Note that the output of U506, an 8 bit DAC is summed with the output of U505. This 8 bit DAC corrects for offset errors which can accumulate as analog voltages pass through buffers, S/H amps, and comparators. These offsets are measured after each unit is manufactured, and values to compensate for these offsets are placed in the unit's ROM. The polarity of the offset-corrected 12 bit DAC is set by 2/4 U511 and the SIGN bit yielding 13 bits of resolution from -10.24 to +10.24 volts.

D/A's

In addition to providing reference voltages for A/D conversion, the DAC output voltage may be multiplexed by U507 to one of eight sample and hold amplifiers which provide analog output and control voltages. The microprocessor refreshes each S/H amplifier every few milliseconds to prevent droop. Two of these outputs are available as general programmable outputs on the rear panel. Two are used to program the band pass filter and the reference oscillator phase shift. One output is subtracted from the lock-in output in U508 to provide a variable offset and another is the rms noise output. The remaining two outputs generate the magnitude and phase output voltages.

Expand

3/4 U511 and 4/4 U1202 are the expand amplifiers. They provide a selectable gain of 10 to the channel 1 and 2 outputs just before the output buffers.

Front Panel

There are 71 led's on the front panel controlled by 9 serial-in, parallel-out shift registers. 8 of the shift registers are written to simultaneously and the 9th is written separately. 8 consecutive write operations are required to set the LED's in each case. The liquid crystal displays are managed by the display controllers, U6101, U6102, and U6103. Exclusive-or gates U6104, U6105 and U6106 drive the left over segments. Latches U6107 and U6108 provide the logic bits for these extra segments as well as the keyboard row strobes. U6109 reads the switch closures as the rows are scanned.

Microprocessor Control

The microprocessor, U701, is a Z80A CPU clocked at 4 Mhz. 16K bytes of firmware are stored in the ROM, U702. U703 is a 2K byte static RAM, backed-up by a lithium battery. A power-down standby circuit, Q701, preserves the RAM contents when the power is turned off. The battery has a life of 5-10 years. The CPU has power-up and power-down resets to prevent erroneous execution during turn-on or short sags in the line voltage.

U704 is a 3-channel counter. One channel generates the baud rate for the RS232 interface while the other two are used to measure the frequency or period of the reference oscillator. U709 provides a gate pulse to counter 0. Multiplexer U708 selects whether the gate is a single period of the reference (period measurement) or a gate of known duration (frequency measurement). Counter 1 is a programmable divide by N counter whose output is either counted for one period of the reference, or, generates the gate pulse during which reference pulses are counted.

I/O addresses are decoded by U705, U706, and U707. The microprocessor controls the lock-in functions through I/O ports U714-U721. U713 generates an interrupt to the CPU every 4 msec to keep the microprocessor executing in real time.

RS232 Interface

The RS232 interface uses an 8251A UART, U801, to send and receive bytes in a bit serial fashion. Any standard baud rate from 300 to 19.2K baud may be selected with the configuration switches. The X16 transmit and receive clock comes from counter 2 of U704. The RS232 interface is configured as DCE so that a terminal may be connected with a standard cable. When a data byte is received by the UART, the

RxRDY output interrupts the CPU to prevent the data from being overwritten.

GPIB Interface

The interface to the GPIB is provided by U802, an MC68488 General Purpose Interface Adapter (GPIA). The GPIB data and control lines are buffered by drivers U808 and U811. Because the GPIA uses a 1 MHz clock, wait states are provided by U805 to synchronize I/O transactions with the 4 MHz CPU. The GPIA interrupts the CPU whenever a GPIB transaction occurs which requires the CPU's response. (The GPIB address is set by switch bank SW1.)

Power Supplies

The line transformer provides two outputs, 40Vac and 15Vac, both center tapped. The transformer has dual primaries which may be selected by the voltage selector card in the fuse holder. The 15Vac is rectified by diode bridge BR2 and passed to 5V regulator U909. The output of U909 powers the microprocessor and its related circuitry. The 40Vac output is half-wave rectified by BR1 and regulated by U901 and U902 to provide +20V and -20V. These two dc voltages are then regulated again by 15V regulators U903-U908. Each 15V regulator powers a separate section of the lock-in to reduce coherent pick up between sections. U911 and U912 provide plus and minus 7.5V and U910 generates +5V for the analog circuits.

Internal Oscillator

The internal oscillator is on a small circuit board attached to the rear panel of the instrument. Local regulators, Q1 and Q2, provide power to the board. The VCO input is internally pulled up by R12. This pulls the VCO input to 10V when the VCO input is left open. 2/4 U1 translates the VCO input voltage to provide a negative control voltage to U2, the function generator. P3 adjusts the VCO calibration. U2 is a sine wave generator whose frequency range is selected by the VCO Range switch and capacitors, C4-C6. P2 adjusts the sine wave symmetry at low frequencies. 4/4 U1 buffers the output of U2. P1 adjusts the amplitude of the output sine wave. The output amplitude on the SIne Out is selected by the amplitude switch. The output impedance is 600 Ω.

Calibration and Repair

This section details calibration of the instrument. Calibration should be done only by a qualified electronics technician.

********* WARNING *********

The calibration procedure requires adjusting the instrument with power applied and so there is a risk of personal injury or death by electric shock. Please be careful.

Most of the calibration parameters are determined by a computer aided calibration procedure after burn-in at the factory. These calibration parameters are quite stable and so will not need to be adjusted. Calibration parameters which may need field adjustment are detailed below.

Multiplier Adjustments

On the **HIGH** dynamic reserve setting, there can be some reference frequency feedthrough. This section describes how to null this unwanted output.

This adjustment requires an oscilloscope and a signal generator which can provide a 500Hz reference signal.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **LOCAL** key down.

Select voltage input **A** and connect a 50 Ω terminator or shorting plug to the **A** input BNC connector. Connect the 500 Hz reference signal to the reference input. Set the **SENSITIVITY** to **1mV** and the **DYN RES** to **HIGH**. The **PRE TIME CONSTANT** should be set to **1mS** and the **POST TIME CONSTANT** to **NONE**. Connect the scope to the **CHANNEL 1 OUTPUT** on the front panel. Set the scope to 2V/div and 5mS/div. Externally trigger the scope using the reference input signal.

After about 90 seconds, the scope display should show a 500 Hz sine wave on a 30 Hz (500/16 Hz) square wave. Remove the four screws holding the top panel on. Slide the top panel back about half way. Using a small screwdriver, adjust P402 at location D2 to minimize the 500 Hz output. Adjust P403 at location C2 to minimize the 30 Hz output.

Now set the both time constants to **1S**. Adjust P404 at location F4 to zero the output. This adjustment has a range of 20% of full scale on the **HIGH** dynamic reserve setting. (2% on **NORM** and 0.2% on **LOW**). This zeroes the DC output of Channel 1 on all dynamic reserve ranges.

Now connect the scope to the **CHANNEL 2 OUTPUT**. Set the **PRE TIME CONSTANT** to **1mS** and the **POST TIME CONSTANT** to **NONE**. Adjust P1102 to minimize the 500 Hz output. Adjust P1103 to minimize the 30 Hz output. Set both time constants to **1S**. Adjust P1104 to zero the output. All three potentiometers are located on the plug-in board in the center of the main circuit board.

Replace the top panel.

Amplifier and Filter Adjustments

This section describes how to adjust the Common Mode Rejection and Line notch filter frequencies. An oscilloscope and a signal generator which can provide an accurate line frequency and twice line frequency sine wave are required.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **LOCAL** key down.

Remove the four screws holding down the top panel. Slide the panel back about halfway.

CMRR

Set the reference frequency to 100 Hz. It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Now set the input selector to **A-B** and connect the signal to both the **A** and **B** inputs. Set the **SENSITIVITY** to **20μV**, the **DYN RES** to **NORM** and the **BANDPASS** filter **IN**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, and 10mS/div. Externally trigger the scope using the reference input signal.

The CMRR is adjusted by the single turn potentiometer located at A1 under the single hole at the front of the signal shield. (The shield is the aluminum box on the left side of the main board). Using a small screwdriver, carefully adjust the potentiometer to minimize the 100 Hz output on the scope. Set the **DISPLAY** to **R,Ø** and the

sensitivity to 5μV and minimize the **R** output on the Channel 1 meter.

Notch Filters

Set the reference frequency to 60.0 Hz (50.0 Hz). It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Set the **LINE NOTCH** to **IN**, the **SENSITIVITY** to **10mV**, and the **DYN RES** to **LOW**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, 10mS/div. Trigger the scope externally using the reference input signal.

The **LINE NOTCH** frequency and depth are adjusted by the pair of 20 turn potentiometers located under the middle two holes in the signal shield (row 4 on the circuit board). Using a small screwdriver, carefully adjust one pot until the line output on the scope is minimized. Then adjust the other pot until the output is minimized. Iterate between the two pots until there is no further improvement. Set the **SENSITIVITY** to **5mV**, **2mV**, and **1mV**, repeating the adjustments at each sensitivity.

Repeat this procedure using a reference frequency of 120.0 Hz (100.0 Hz) and the **LINEX2 NOTCH** filter. The **LINEX2 NOTCH** is adjusted by the pair of 20 turn potentiometers located under the back two holes in the signal shield (row 5 on the circuit board).

Replace the top panel.

Replacing the Front-End Transistors

Both the voltage and current front end transistors (Q101 and Q102) are 2N6485 (IMF6485) dual JFETS. These transisitors are selected at the factory to meet the noise specifications.

This section outlines their replacement procedure in the event that they become damaged during use.

1)**Remove the AC power cord from the unit.**

2)Remove top and bottom panels.

3)Release the signal shields by removing the four screws which hold it onto the circuit board. Be careful not to lose the the nuts. Carefully slide the shields back and then lift them out.

4)The input transistors are located on the main board, just behind the input selector switch. Q101 is the voltage (**A**, **A-B**) front end, and Q102 is the current (**I**) front end. Desolder and replace the appropriate transistor.

5)Replace the signal shields. Be careful to check that the shields do not touch any circuit board traces around their edges.

6)Replace the top and bottom panels.

7)If Q101, the voltage front end has just been replaced, the Common Mode Rejection needs to be readjusted using the procedure described in the Amplifier Adjustments section.

Appendix A:
Noise Sources and Cures

Noise, random and uncorrelated fluctuations of electronic signals, finds its way into experiments in a variety of ways. Good laboratory practice can reduce noise sources to a manageable level, and the lock-in technique can be used to recover signals which may still be buried in noise.

Intrinsic Noise Sources

Johnson Noise. Arising from fluctuations of electron density in a resistor at finite temperature, these fluctuations give rise to a mean square noise voltage,

$$\bar{V}^2 = \int 4kT\,\mathrm{Re}[Z(f)]\,df = 4kTR\,\Delta f$$

where k=Boltzman's constant, 1.38×10^{-23}J/°K; T is the absolute temperature in Kelvin; the real part of the impedance, Re[z(f)] is the resistance R; and we are looking at the noise source with a detector, or ac voltmeter, with a bandwidth of Δf in Hz. For a 1MΩ resistor,

$$(\bar{V}^2)^{1/2} = 0.13\ \mu V/\sqrt{Hz}$$

To obtain the rms noise voltage that you would see across this 1MΩ resistor, we multiply $0.13\mu V/\sqrt{Hz}$ by the square root of the detector bandwidth. If, for example, we were looking at all frequencies between dc and 1 MHz, we would expect to see an rms Johnson noise of

$$(\bar{V}^2)^{1/2} = 0.13\ \mu V/\sqrt{Hz} * (10^6\ Hz)^{1/2} = 130\ \mu V$$

'1/f Noise'. Arising from resistance fluctuations in a current carrying resistor, the mean squared noise voltage due to '1/f' noise is given by

$$\bar{V}^2 = A\,R^2\,I^2\,\Delta f/f$$

where A is a dimensionless constant, 10^{-11} for carbon, R is the resistance, I the current, Δf the bandwidth of our detector, and f is the frequency to which the detector is tuned. For a carbon resistor carrying 10 mA with R = 1k, $\Delta f = f = 1$Hz, we have

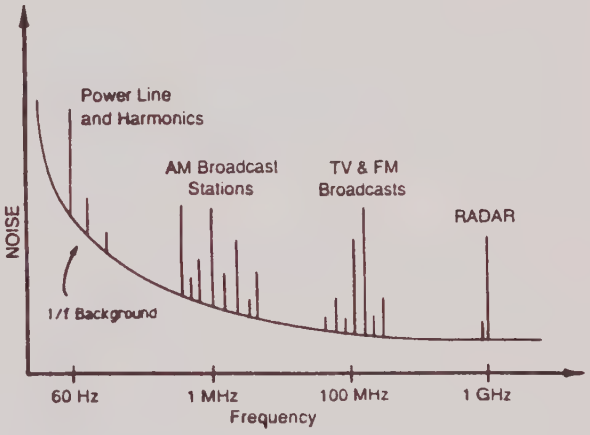
$$V_{noise} = 3\ \mu Vrms$$

And Others. Other noise sources include flicker noise found in vacuum tubes, and generation and recombination noise found in semiconductors.

All of these noise sources are incoherent. Thus, the total noise is the square root of the sum of the squares of all the incoherent noise sources.

Non-Essential Noise Sources

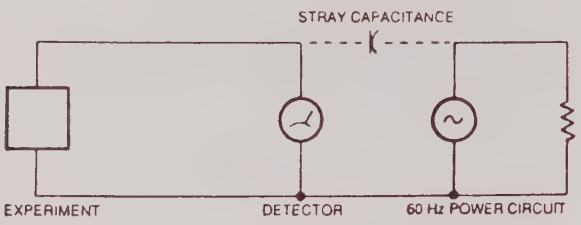
In addition to the "intrinsic" noise sources listed above there are a variety of "non-essential" noise sources, i.e. those noise sources which can be minimized with good laboratory practice. It is worthwhile to look at what might be a typical noise spectrum encountered in the laboratory environment:



Noise Spectrum

Some of the non-essential noise sources appear in this spectrum as spikes on the intrinsic background. There are several ways which these noise sources work their way into an experiment.

Capacitive Coupling. A voltage on a nearby piece of apparatus (or operator) can couple to a detector via a stray capacitance. Although C_{stray} may be very small, the coupled in noise may still be larger than a weak experimental signal.



Capacitive Noise Coupling

To estimate the noise current through C_{stray} into the detector we have

$$i = C_{stray}\frac{dV}{dt} = jwC_{stray}V_{noise}$$

where a reasonable approximation to C_{stray} can be made by treating it as parallel plate capacitor. Here, w is the radian frequency of the noise source (perhaps $2 * \pi * 60Hz$), V_{noise} is the noise voltage source amplitude (perhaps 120 Vac). For an area of A = $(.01\ m)^2$ and a distance of d = 0.1m, the 'capacitor' will have a value of 0.009 pF and the resulting noise current will be 400pA. This meager current is about 4000 times larger than the most sensitive current scale that is available on the SR530 lock-in.

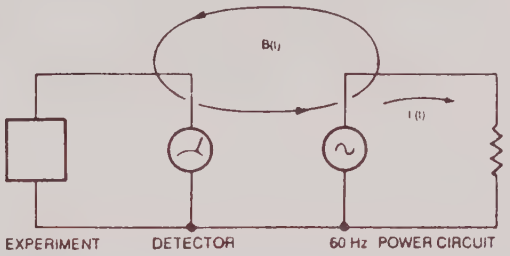
Cures for capacitive coupling of noise signals include:

1) removing or turning off the interfering noise source,

2) measuring voltages with low impedance sources and measuring currents with high impedance sources to reduce the effect of i_{stray},

3) installing capacitive shielding by placing both the experiment and the detector in a metal box.

Inductive Coupling. Here noise couples to the experiment via a magnetic field:



Inductive Noise Coupling

A changing current in a nearby circuit gives rise to a changing magnetic field which induces an emf in the loop connecting the detector to the experiment. ($emf = d\Phi_B/dt$.) This is like a transformer, with the experiment-detector loop as the secondary winding.)

Cures for inductively coupled noise include:

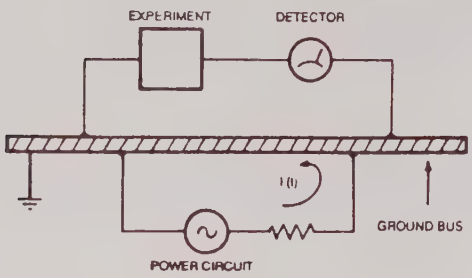
1) removing or turning off the interfering noise source (difficult to do if the noise is a broadcast station),

2) reduce the area of the pick-up loop by using twisted pairs or coaxial cables, or even twisting the 2 coaxial cables used in differential hook-ups,

3) using magnetic shielding to prevent the magnetic field from inducing an emf (at high frequencies a simple metal enclosure is adequate),

4) measuring currents, not voltages, from high impedance experiments.

Resistive Coupling (or 'Ground Loops'). Currents through common connections can give rise to noise voltages.



Resistive Coupling

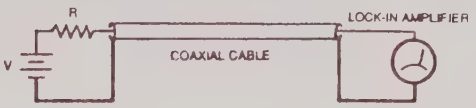
Here, the detector is measuring the voltage across the experiment, plus the voltage due to the noise current passing through the finite resistance of the ground bus. This problem arises because we have used two different grounding points which are not at exactly the same potential. Some cures for ground loop problems include:

1) grounding everything to the same physical point,

2) using a heavier ground bus to reduce the potential drop along the ground bus,

3) removing sources of large currents from ground wires used for small signals.

Microphonics provides a path for mechanical noise to appear as electrical noise in a circuit or experiment. Consider the simple circuit below:



The capacitance of a coaxial cable is a function of its geometry so mechanical vibrations will cause the cable capacitance to vary with time. Since C=Q/V, we have

$$C\frac{dV}{dt} + V\frac{dC}{dt} = \frac{dQ}{dt} = i$$

so mechanical vibrations will cause a dC/dt which in turn gives rise to a current i, which will affect the detector. Ways to eliminate microphonic signals include:

1) eliminate mechanical vibrations,

2) tie down experimental cables so they will not sway to and fro,

3) use a low noise cable that is designed to reduce microphonic effects.

Thermocouple Effect. The emf created by dissimilar metal junctions can give rise to many microvolts of dc potential, and can be a source of ac noise if the temperature of the junction is not held constant. This effect is large on the scale of many low level measurements.

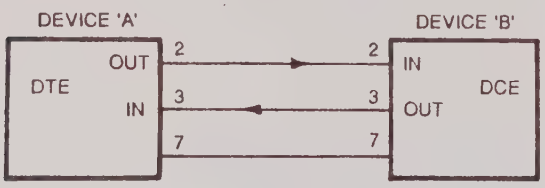
Appendix B:
Introduction to the RS232

The 'RS232' is a standard for bit serial asynchronous data communication. The standard defines the format for data transmission, the electrical specifications for the signal levels, and the mechanical dimensions of connectors.

Despite the definition of a standard, there are so many permutations of control lines, data formats, and transmission speeds, that getting two RS232 devices to communicate usually requires some work.

In this section, we will provide some basic information to aid you in connecting your RS232 device to the SR530 Computer Interface.

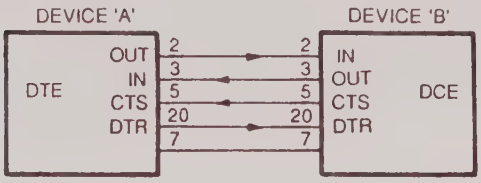
CASE 1 - The Simplest Configuration.



In this case, one wire is used to send data from device A to device B and another wire is used to send data from device B to device A. Notice that pin 2 is an output on device A and an input on device B. (It is good practice to run the ground, pin 7, between the devices as well). The RS232 defines two types of devices; DTE (Data Terminal Equipment) and DCE (Data Communications Equipment.) An RS232 port on a computer may be either a DTE or DCE but nearly every terminal with an RS232 port is a DTE. RS232 ports on a computer which are intended to connect to a modem, such as the COM1: port on the IBM PC, are DTE. The SR530 is configured as DCE, and so it may be directly connected to ASCII terminals and to the COM: ports on IBM PC's and compatibles.

As an example, consider connecting an RS232 ASCII computer terminal to the SR530 using a 2 wire link. The terminal is a DTE and the SR530 is a DCE. To operate correctly, the SR530 and the terminal must have the same settings for baud rate, parity, and number of stop bits. The control lines in the RS232 Standard, which are used to indicate that a device is ready to accept data, must also be connected correctly at the terminal end. If the terminal responds to a control line, it will believe that the SR530 is not ready to accept data (because the line is not passed in this example) and will therefore not send any data.

CASE 2 - RS232 with Control Lines.



The data lines are the same as in Case 1. In addition to the data lines, there are two control lines used:

CTS - Pin 5
"Clear to send" is a signal asserted by the DCE to tell the DTE that the DCE is ready to receive data.

DTR - Pin 20
"Data Terminal Ready" is a signal asserted by the DTE to tell the DCE that the DTE is ready to receive data.

The SR530 responds to the control lines as follows:

1) If the lines are not connected, the SR530 assumes that you are ready to receive data.

2) Data will not be transmitted from the SR530 if the DTR line (pin 20) is low. This is useful in the case when your program is not yet ready to receive data. If data transmission is not suspended, then data may be overwritten in your computer's UART (as it is not being retrieved by the program and so will be lost.) When this happens, the 'over-run' flag will be set in your computer's UART and it may be recognized by the operating system, generating an error message such as "I/O Device Error" (See the "W" command in the SR530 Command List for another way to slow data transmission.)

Baud Rate

The RS232 baud rate of the SR530 is switch selectable from 300 to 19.2K baud (see configuration switch setting in the front of this manual.) 19.2K baud means that data is transmitted at 19,200 bits/second. With one start bit, 2 stop bits, 8 data bits, and no parity bits, each ASCII character requires 573 µsec to be transmitted (11bits/19.2K baud.) The typical data string 5.1270<cr> has 7 characters, requiring 4 msec to be sent.

Stop Bits

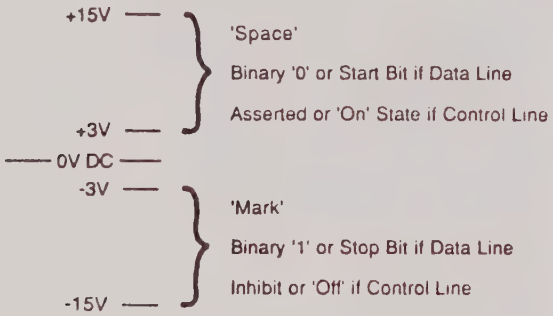
Generally, selection of 2 stop bits will result in fewer data transmission errors.

Parity

The Parity bit provides a check against faulty data transfer. It is not commonly used in local data transmission environments. If the parity option is selected, the SR530 will transmit 8 data bits and a parity bit, however, no parity check of incoming data is done.

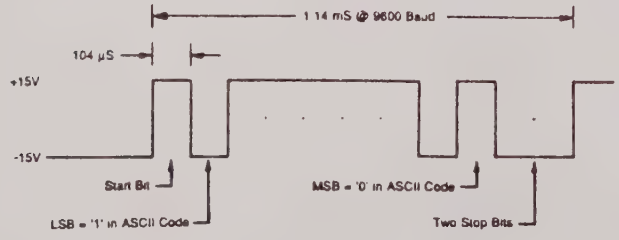
Voltage Levels

The RS232 uses bipolar voltage levels:



The control lines use positive logic. For example, the DCE tells the DTE that it is clear to send (CTS) by placing > +3 VDC on pin 5 of the interface. Similarly, the DTE can tell the DCE that it is not ready by placing -3 VDC on pin 20 (DTR) of the interface.

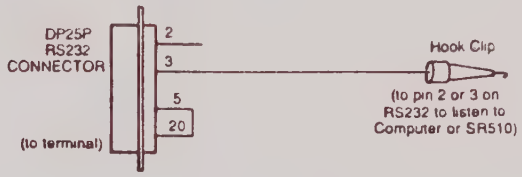
The data lines, pins 2 and 3, use negative logic. A 'zero' bit is represented by a positive voltage and a 'one' bit is represented by a negative voltage. A start bit is a positive voltage and a stop bit is a negative voltage. Data is transmitted with the least significant bit first. The letter 'A', which has the ASCII code 41H (0100 0001), would appear as follows:



If a parity option was selected, the parity bit would be sent after the 8th data bit, but before the first stop bit.

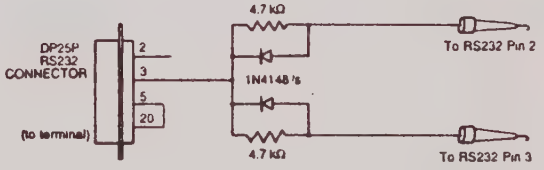
Final Tip

When you are trying to get the RS232 to work with your computer, it is helpful to be able to 'eavesdrop' on the RS232 data lines going between the SR530 and the computer. This can be done with an ASCII RS232 terminal and the following connector:



To test the connector, place the hook clip on pin 2 of the same connector (shorting pin 2 to pin 3.) Now, when you type at the terminal keyboard, data transmitted from pin 2 is received at pin 3 and displayed on the terminal screen. To use as a debugging tool, attach the hook clip to either pin 2 or pin 3 of the RS232 cable on the SR530 to show either data sent from the Computer or the SR530. The baud rate, parity, and stop bits of the terminal must match those of the SR530 and the computer. If your terminal has a mode which will display control characters (such as carriage returns and line feeds) it is helpful to operate in that mode.

A variant of the 'eavesdropping' approach is diagrammed below:



With this cable arrangement, the ASCII terminal can listen to the data passing in both directions. The only drawback is that the terminal will display garbled data if both devices transmit data at the same time.

Appendix C:
Introduction to the GPIB

The IEEE-488 Standard specifies the voltage levels, handshake requirements, timing, hardware details, pinout and connector dimensions for a 16 line, bit parallel bus. Many instruments may be connected in series to communicate over the same cable. Because the bits are passed in parallel, the GPIB is faster than the RS232.

The controller (generally your computer) coordinates data transfer on the bus by designating all participating instruments (including itself) as either a talker or a listener. Listeners can receive data placed on the bus by the Talker. Devices can have the capacity to operate in either mode. The address of each device is set by switches in the device and must be between 0 and 30.

Bus Description

Byte Transfer Control Group. This consists of 3 negative logic lines that implement the GPIB handshaking. The NRFD (Not Ready For Data) line is held low by any designated listener who is not ready to accept data. When every listener is ready, the line goes high and the talker may release data to the bus. After data is on the bus, the talker pulls the DAV (Data Valid) line down. At this point, each listener retrieves the data. Before and during the retrieval of the data, the listener holds the NDAC (No Data Accepted) line down. When every listener has received the data, the NDAC line goes high, allowing the talker to release the DAV line high. Finally, the listener pulls down the NDAC line until another transfer is initiated.

Data Bus: There are eight data lines which use negative logic and pass the bits of each byte in parallel.

General Interface Lines: These five lines operate independently of the handshake lines and use negative logic.

1) The EOI (End or Identify) line is used by the talker to designate the end of message.

2) The SRQ (Service Request) line is used by any device to ask for service. The controller can serial poll each device (each device returns an 8 bit status byte) to determine who needs attention. It can also do a parallel poll using the EOI and ATN lines where each device is assigned a single data line.

3) The ATN (Attention) line makes both talkers and listeners accept information and passes control of the DAV line to the controller. This line is used by the controller to identify talkers and listeners through their addresses.

4) The REN (Remote Enable) line changes the status of an instrument from local to remote.

5) The IFC (Interface Clear) line clears the bus of all data and activity.

Though GPIB is a very powerful interface, strict protocol must be observed for it to operate successfully.

Appendix D:
Program Examples

All of the program examples which follow do the same thing, only the computer, language, or interface is changed. The programs read the Channel 1 and 2 Outputs and write the results to the computer screen. In addition, the X6 analog output port is ramped from 0 to 10V.

Program Example 1:
IBM PC, Basic, via RS232

In this example, the IBM PC's ASYNC port (known as COM1: or AUX: to DOS users) will be used to communicate with the SR530. Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
10 '    EXAMPLE PROGRAM TO READ THE SR530 OUTPUTS AND RAMP THE X6 ANALOG OUTPUT
20 '    USING IBM PC BASICA AND THE COM1: RS232 PORT.
30 '    THE RAMP ON X6 CAN BE WATCHED BY SETTING THE SR530 DISPLAY TO A/D.
40 '
50 '
60 '    ON THE REAR PANEL OF THE SR530, SET SWITCH #1 OF SW2 DOWN
70 '    AND ALL OTHER SWITCHES IN SW2 UP. (9600 BAUD, NO PARITY)
80 '
90 OPEN "COM1:9600,N,8,2,CS,DS,CD" AS #1
100 '    SET UP COM1: PORT TO 9600 BAUD, NO PARITY, 8 DATA BITS, 2 STOP BITS,
110 '                        IGNORE CTS (CLEAR TO SEND), DSR (DATA SET READY),
120 '                       AND CD (CARRIER DETECT).
130 '
140 PRINT #1,"    "      'CLEAR UART BY SENDING SPACES
150 PRINT #1,"Z"         'RESET SR530
160 FOR I = 1 TO 200: NEXT I    'WAIT FOR RESET TO FINISH
170 '
180 X = 0        'INIT X6 OUTPUT TO ZERO
190 '
200 PRINT #1,"Q1"        'READ CHANNEL 1 OUTPUT
210 INPUT #1,V1          'INTO V1
220 PRINT #1,"Q2"        'READ CHANNEL 2 OUTPUT
230 INPUT #1,V2          'INTO V2
240 '
250 PRINT "CH1 = ";V1;"         CH2 = ";V2
260 '
270 X = X + .0025       'INCREMENT X6 OUTPUT BY 2.5 MV
280 IF X > 10 THEN X = 0         'RESET X6 RAMP
290 PRINT #1, USING "X6,##.###";X        'SET X6 OUTPUT VOLTAGE
300 '
310 GOTO 200             'LOOP FOREVER
```

Program Example 2: IBM PC, Microsoft Fortran v3.3, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR575 disk. These routines allow for simple interfacing to the SR530 at 19.2 kbaud from FORTRAN programs.

To use these routines, the file 'for232.inc' (also on the SR575 disk) must be 'included' in the FORTRAN source.

Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
$storage:2
$include:'for232.inc'
C       for232.inc must be included to call subroutines in RS232.OBJ
C       link with RS232.OBJ (on SR575 disk)
C       RS232.OBJ defines:
C             init
C                         initializes COM1: to 19.2 kbaud
C             txstr (str)  str is a string terminated with '$'
C                         transmits str to COM1:
C             rxstr (str)  str must be declared with length of 15 or greater
C                         fills str with string received from COM1:
C             If and error occurs, nocom is called.
C             Nocom should be a FORTRAN subroutine in your program.

      program ex2

      character*20 str1,str2,str3

C     Example program to read the SR530 outputs and ramp the
C     X6 analog output using Microsoft FORTRAN v3.3 and the
C     COM1: port. Set all switches in SW2 to UP on SR530
C     for 19.2 kbaud.

C     The ramp on X6 can be watched by setting the SR530
C     display to D/A.

C     initialize COM1: port to 19.2 kbaud
      call init
C     set character wait interval to zero
      call txstr('w0$')

C     reset X6 to zero
      x6=0.0

C     read channel 1 output into string variable str1
20    call txstr('q1$')
      call rxstr(str1)
C     read channel 2 output into string variable str2
      call txstr('q2$')
      call rxstr(str2)
```

```
c       convert string variables into real variables v1 and v2
        read (str1,1000) v1
        read (str2,1000) v2
1000    format (bn,f10.0)

c       print results to screen
        write(*,2000) v1,v2
2000    format(' Channel 1=',G10.3,3x,'Channel 2 =',G10.3)

c       ramp x6 by 2.5 mV
        x6 = x6 + .0025
        if (x6.gt.10) x6 = 0.0
c       make x6 command string
        write (str3,3000) x6
3000    format ('x6,',f7.3,'$')
        call txstr(str3)

c       and loop forever
        goto 20

        stop
        end

c       ********************************************************
        subroutine nocom

c       in case of a timeout error, this routine runs
c       put your error handler here.

        write(*,*) char(7)
        write(*,*) 'RS-232 Timeout Error!'

        stop
        end
```

Program Example 3: IBM PC, Microsoft C v3.0, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR575 disk. These routines allow for simple interfacing to the SR530 at 19.2 kbaud from C programs.

To use these routines, the large model must be used. Compile with the /AL switch and link with RS232.OBJ.

Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
#include <stdio.h>

/*      Compile with >MSC program name/AL;
        link with RS232.OBJ (on SR575 disk)
                RS232.OBJ defines:
                init ()
                                initializes COM1: to 19.2 kbaud
                txstr (str)
                    char *str;  str must terminate with '$' char
                                sends string str to COM1:
                rxstr (str)
                    char *str;  str must be declared with 15 characters
                                  or more length.
                                fills str with string received from COM1:

                If an error occurs, your procedure nocom() is called.
                Nocom() must be a C procedure in your program.

        Example program to read the SR530 outputs and ramp the
        X6 analog output using Microsoft C v3.0 (large model) and the
        COM1: port. Set all switches in SW2 to UP on SR530
        for 19.2 kbaud.

        The ramp on X6 can be watched by setting the SR530
        display to D/A.
*/

main ()
      {
      char str1[20], str2[20], str3[20];
      float v1,v2,x;

      init ();                  /* init COM1: port to 19.2 kbaud */
      txstr ("w0$");            /* set character interval to 0 */

      x = 0;
      while (1)
            {
            txstr ("q1$");              /* read channel 1 output */
            rxstr (str1);               /* into str1 */
            sscanf (str1, "%f", &v1); /* scan str1 for a float variable */
```

```
            txstr ("q2$");              /* read channel 2 output */
            rxstr (str2);               /* into str2 */
            sscanf (str2, "%f", &v2); /* scan str2 for a float variable */

            x += 0.0025;                /* increment x6 output by 2.5 mV */
            if (x >= 10) x = 0;
            sprintf (str3, "X6,%f$", x);      /* make x6 command string */
            txstr (str3);                     /* send x6 command */

            /* print results to screen */
            printf ("Channel 1 = %10.3G      Channel 2 = %10.3G\n", v1, v2);
            }
        }
/* ************************************************** */
nocom ()
        /* error handling routine goes here */
        {
        printf("RS232 Timeout Error\n");
        putch (7);
        exit ();
        }
```

Program Example 4: IBM PC,Microsoft Basic, via GPIB

This program requires the Capital Equipment Corporation GPIB card for the IBM PC or XT. It has firmware in ROM to interface high level languages to the GPIB.

Subroutine calls in Microsoft BASIC are done to memory locations specified by the name of the subroutine. The address is relative to the segment address specified by the DEF SEG statement preceding CALL.

In this program, the CEC card's ROM starts at OC0000H, the system controller's address is 21, and the SR530 has been assigned as GPIB address 23.

To monitor the GPIB activity with an RS232 terminal, SW1-6 should be down, and the ASCII terminal should be attached to the rear panel RS232 connector.

```
10 '    EXAMPLE PROGRAM TO READ THE SR530 OUTPUTS AND RAMP THE X6 ANALOG OUTPUT
20 '    USING IBM PC BASICA AND THE CAPITAL EQUIPMENT CORP. GPIB INTERFACE CARD
30 '
40 '     THE RAMP ON X6 CAN BE WATCHED BY SETTING THE SR530 DISPLAY TO D/A.
50 '
60 '    ON THE SR530 REAR PANEL, SET SWITCHES #4 AND #6 ON SW1 TO DOWN (DEVICE
70 '    ADDRESS = 23, RS232 ECHO ON) AND SWITCH # 1 ON SW2 TO DOWN (RS232 BAUD
80 '    RATE = 9600). ALL OTHER SWITCHES SHOULD BE UP.
90 '    NOTE THAT THE RS232 ECHO IS FOR DEBUGGING AND DEMONSTRATION PURPOSES,
100 '   UNDER NORMAL CONDITIONS, SWITCH # 6 OF SW1 SHOULD BE UP SINCE THE RS232
110 '   ECHO SLOWS DOWN THE GPIB INTERFACE.
120 '
130 DEF SEG = &HC000    'BASE ADDRESS OF CEC CARD
140 INIT=0: TRANSMIT=3: RECV=6:         'ADDRESSES OF CEC FIRM WARE ROUTINES
150 ADDR%=21: SYS%=0                    'CONTROLLER ADDRESS
160 INZ$ = "IFC UNT UNL MTA LISTEN 23 DATA 'I' 13"
170 '
180 Q1$ = "IFC MTA LISTEN 23 DATA 'Q1' 13"
190 Q2$ = "IFC MTA LISTEN 23 DATA 'Q2' 13"
200 X6$ = "IFC MTA LISTEN 23 DATA 'X6,"
210 LISN$ = "IFC UNT UNL MLA TALK 23"
220 '
230 '
240 CALL INIT(ADDR%,SYS%)       'INIT CEC CARD
250 CALL TRANSMIT(INZ$,STATUS%) 'RESET SR530
260 GOSUB 600                   'CHECK TRANSMIT STATUS
270 '
280 X = 0       'INIT X6 OUTPUT TO ZERO
290 '
300 CALL TRANSMIT(Q1$,STATUS%)  'READ CHANNEL 1 OUTPUT
310 GOSUB 600
320 GOSUB 510                   'GET RESULT
330 V1 = VAL(ANS$)              'INTO V1
340 '
350 CALL TRANSMIT(Q2$,STATUS%)  'READ CHANNEL 2 OUTPUT
360 GOSUB 600
370 GOSUB 510                   'GET RESULT
380 V2 = VAL(ANS$)              'INTO V2
390 '
400 PRINT "CH1 = ";V1;"         CH2 = ";V2
410 '
```

```
420 X = X + .0025       'INCREMENT X6 OUTPUT BY 2.5 MV
430 IF X>10 THEN X = 0          'RESET RAMP
440 X$ = X6$ + STR$(X) + "' 13"         'MAKE X6 COMMAND STRING
450 CALL TRANSMIT (X$,STATUS%)          'SET NEW X6 VOLTAGE
460 GOSUB 600
470 '
480 GOTO 300    'LOOP FOREVER
490 '
500 '    GET AN ANSWER STRING FROM THE SR530
510 CALL TRANSMIT(LISN$,STATUS%)        'MAKE SR530 A TALKER
520 GOSUB 600
530 ANS$=SPACE$(10)                     'INIT ANSWER STRING
540 CALL RECV(ANS$,LENGTH%,STATUS%)     'READ RESULT INTO ANS$
550 GOSUB 600
560 RETURN
570 '
580 '
590 '    CHECK STATUS OF LAST TRANSMISSION FOR ERRORS
600 IF STATUS%=0 THEN RETURN   'STATUS OKAY
610 PRINT "STATUS CODE = ";STATUS%;" ON GPIB: ERROR"
620 STOP
```

Program Example 5: HP85 via GPIB

This program provides an example of an HP85 program using the GPIB interface which could be used to control the lockin amplifier. In this example, the SR530 should be addressed as device #16 by setting the switch bank SW1 per the instructions Page 7.

```
 10 X=0
 20 OUTPUT 716 ; "Q1"
 30 ENTER 716 ; V1
 40 DISP "CH1 = " ; V1
 50 OUTPUT 716 ; "Q2"
 60 ENTER 716 ; V2
 70 DISP "CH2 = " ; V2
 80 X = X + .0025
 90 IF X>10 THEN X=0
100 OUTPUT 716 ; "X6,";X
110 GOTO 20
```

SR575

A Software Package for the SR530 Lock-in Amplifier

SR575 IBM PC Software

Introduction

The SR575 Lock-in Data Acquisition software package adds a new dimension to your SR530 lock-in amplifier. With the SR575 you can easily acquire, display, and manipulate data from your lock-in amplifier directly on your personal computer. The SR575 has been extensively tested and can be running on your computer in just a few minutes. And since the source code for the SR575 program is available (for a nominal charge) you can modify the program to include any special features that may be required in your application.

To help familiarize yourself with the program, we will guide you through a detailed example which illustrates many of its features. In order to follow the example, you do not have to connect your computer to an SR530; the program is configured when shipped in a special demonstration mode that allows it to be used without an SR530. Of course, you won't be able to acquire any data in this mode, but we've provided a data file on your program disk to illustrate some of the SR575's graphics and data manipulation capabilities.

Before starting the example please read the section below which describes the few simple steps necessary to get the SR575 running on your computer.

Getting Started

To run the SR575 program you'll need the following:

IBM PC/XT/AT or compatible computer
320 Kbytes of RAM
720 x 348 Monochrome Graphics Card
DOS 2.1 (or higher) operating system

To connect your computer to the SR530 lock-in amplifier you'll also need one of the following:

RS232 port configured as COM1:
OR
National Instruments GPIB card
OR
Capital Equipment Corp. GPIB card

Before running the SR575 program, you must run three auxilliary programs which are found on your program disk. To insure that this is done, we recommend that you include the following statements in your AUTOEXEC.BAT file:

HGC FULL
VIDEO
PRNSRS

The first program initializes the monochrome graphics card to the full graphics mode. The second installs new graphics drivers to expand the graphics capabilities available to the program beyond those provided by the ROM BIOS. The third program installs drivers which allow graphics generated by the SR575 to be dumped to an Epson-type printer with graphics capabilities (such as the FX-80).

If you would like to connect your SR530 lock-in amplifier to the computer at this time, you'll also have to run the program SR5CON.EXE found on your program disk. SR5CON will ask a few questions regarding which of the three supported communications modes: RS232 via the COM1: port, GPIB via the National Instruments Card, or GPIB via the Capital Equipment Corp. card, will be used. The SR5CON program creates a file SR575.CFG, which contains the communications hardware information and which is read by the SR575 program. The SR575.CFG file must always be on the same drive and directory as the SR575.EXE file when the SR575 progam is run.

After running SR5CON, you should connect either the COM1: port or the GPIB port on your computer to the corresponding connector on the back panel of your SR530 with either a GPIB cable or a standard (NOT a null modem) RS232 cable. If you're using RS232, you should set the baud rate of the lock-in to 19.2 Kbaud. This is done by turning all the switches of SW2 on the back panel of the SR530 to the "up" postion. If you're using the GPIB, you'll have to set the lock-in address to the value you selected using SR5CON. The GPIB address is set using switches 1-5 of SW1 on rear panel of the SR530. Also make sure that switch 6 of SW1 is in the "up" position to turn off the GPIB - RS232 echo.

You are now ready to run the SR575 program. Two versions of the program are provided on your disk. The first, SR575.EXE is intended for systems that do not have an 8087/80287 numeric coprocessor. The second, SR575.887, is intended to be used with systems that do have a coprocessor. If you don't have an 8087/80287, you should save the file SR575.887, as acquiring a coprocessor significantly enhances the performance of the program. If you do have a coprocessor, you can rename the file SR575.887 SR575.EXE. Be sure to first save the original non-coprocessor version under a different name in case it is ever needed.

Running the Program

To run the program, type SR575 at the DOS prompt. A title screen will come up giving the version number of the program. After a second or so, the title screen will be replaced by the main stripchart display screen. If the computer is connected to an SR530, the green activity LED should be on, indicating the progam is communicating successfully with the lock-in.

If the the program is not running at this point, check that:

1. You have the correct hardware. (check the list on the previous page)
2. Your computer has at least 320Kbytes of RAM. (use the DOS CHKDSK command)
3. You have run HGC, VIDEO, and PRNSRS

The main display screen has four major display areas. The **status bar**, at the top of the screen displays important status information about the SR530 and the SR575. The **stripchart display** in the center of the screen acts as an electronic stripchart recorder where data from the lock-in is plotted as a function of time. The **virtual front panel**, located at the bottom left of the screen, allows the front panel settings of the lock-in to be viewed and modified from the computer. The **menu area**, at the bottom right of the screen, displays the menu selections currently available to the user. In general, items in the menu area are selected either by pressing the appropriate function key F1- F10 or by manipulating the cursor with the cursor control keys on the computer keyboard. Be sure when running the program that the Num Lock key is off; this allows the numeric keypad on the keyboard to function as cursor control keys.

A Measurement Example

Assuming you have the program running, it's now time to try an example measurement. We will illustrate how the SR575 program can be used to measure the amplitude response of the SR530's 120 Hz notch filter. We'll do this by using the program to generate a voltage ramp on one of the SR530's back panel D/A outputs. This ramp will be used to drive the VCO input of the SR530's internal oscillator generating a frequncy ramp. The SR575 will plot the output of the lock-in as the frequency is ramped through the the notch filter at 120 Hz.

If you are running the program in the demonstration mode, without an SR530, read through the description of how data is acquired and follow the instructions in the section entitled "Using the Demo File." This section will tell you how to recall a file which contains the results of the measurement described below. If you're already talking to an SR530, follow the instructions below for performing the example measurement.

We first need to set up the SR530's internal oscillator. Connect a BNC cable from the SR530's back panel X5 output to the VCO input of the internal oscillator. Since we'll want to scan from about 80 Hz-160 Hz and the range of the SR530's D/A outputs is -10.24 to +10.24 volts, set the internal oscillator for 100Hz/Volt. Also set the oscillator for a 0.1 Volt output sine-wave. Connect the oscillator's "reference out" BNC to the front panel reference input of the SR530. Connect the "sine out" BNC of the oscillator to the "A" input of the SR530 and set the input selector to "A".

Now press the F6 function key to activiate the "lock-in-setup" menu. This will allow you to change the lock-in front panel settings through the virtual front panel. Note that a cursor appears next to the display indicator. Move the cursror to the sensitivity indicator by pressing the "->" key on the keypad once. To adjust the sensitivity of the lock-in use the up and down arrow cursor keys. Note that the senstivity is changed both on the computer screen and on the lock-in front panel. To change the phase setting of the SR530, for instance, use the left and right arrow cursor control keys to move the cursor next to the phase indicator on the virtual front panel. The phase can now be adjusted with the up and down arrow keys.

The lock-in settings for the example measurement are stored in a file "NOTCH.L2A" found on your program disk. To use the file, press F1 in the lock-in setup menu we've just entered. The program will prompt you for a filename. Type A:NOTCH <CR> at the prompt. (Replace A: by whatever drive your program disk is on) The virtual front panel, as well as the SR530 front panel, will change to reflect the settings stored in the file. ".L2A" files are a convenient way to store a set of lock-in settings that can be easily recalled.

Next hit the <Esc> key to return to the main menu. Throughout the program the <Esc> key is used to exit the current function and move upwards towards the main menu. When the main menu appears, press F8 in order to program the SR530's D/A output for our frequency scan. The program will ask which D/A you wish to program; select X5 by moving the cursor over X5 and pressing <CR>.

Since we wish to scan from 80-160 Hz and the oscillator is set for 100 Hz/Volt, use the keypad to select an initial voltage of 0.800 Volts. Note that after this is done, the virtual front panel will show a frequency of about 80 Hz. Select a final voltage of 1.600 Volts, a scan time of 100 sec, a single scan, and a linear scan using the cursor keys and the <CR> key. The main menu should now be visible in the menu area.

We would like to record two things during our example scan; the frequency of the oscillator and the magnitude output of the SR530. To select the values recorded by the program, press the F3 key. You will notice that "Ch. 1" has already been selected. A glance at the display indicator on the virutal front panel shows that Ch. 1 corresponds to the magnitude output of the SR530. To select frequency, move the cursor over the frequency indicator and turn it "on" with the up arrow key. When you press <CR>, notice that "freq" appears on the status bar indicating that it is one of the values recorded by the SR575. To have the program plot frequency, press the "2" key on the keypad. A labeled Y-Axis will appear on the right-hand side of the stripchart display and the status bar will display "freq" in reverse video indicating it is being plotted as well as recorded. Each of the recorded values shown on the status bar can be plotted or not plotted by pressing the correspondingly numbered key on the keypad.

The last thing to be done before actually beginning the scan is to scale the display. Press F7 to enter the scaling menu. The program will ask you to select which one of the quantities on the status bar you wish to scale. Select V using the cursor keys. Pressing F2 now allows you to enter the minimum and maximum values displayed on the screen. Enter "0" for Y_{min} and "0.2" for Y_{max}. The program will rescale the "Y" axis and return to the main menu. Now try scaling the frequency axis for values between 70Hz and 170Hz. When finished, you are ready to begin the scan.

Begin the scan by pressing F1. The frequency and lock-in output will be plotted on the stripchart display in real time. When the plot reaches the right edge of the screen, the display will begin to scroll off to the left. You should see the frequency linearly increasing from 80 Hz to 160 Hz. It will also be easy to see the effect of the notch filter as the frequency approaches 120 Hz. After 100 sec, the scan will stop at about 160 Hz and program will stop taking data.

Using the Demo File

If you are running the program in the demonstration mode you can see the data resulting from the meausrement just decribed by recalling the file "NOTCH.L2D" from your program disk. To do this, press the F4 key in the main menu. Press F1 to recall a file and type "A:NOTCH" at the filename prompt. The data will appear on the stripchart display. The remainder of the example can now be followed as if an SR530 has been connected to the computer.

Manipulating Data on the Screen

Now scroll through the data on the screen using the left and right arrow keys on the keypad. Note that the time corresponding to the left-hand side of the graph is displayed near the bottom left-hand corner of the stripchart display. You can change the scaling of the time axis by pressing F5 from the main menu. Select a time window of 70 seconds with the cursor, press <CR> and then <Esc> to return to the main menu. The data is replotted to reflect the new time axis scaling.

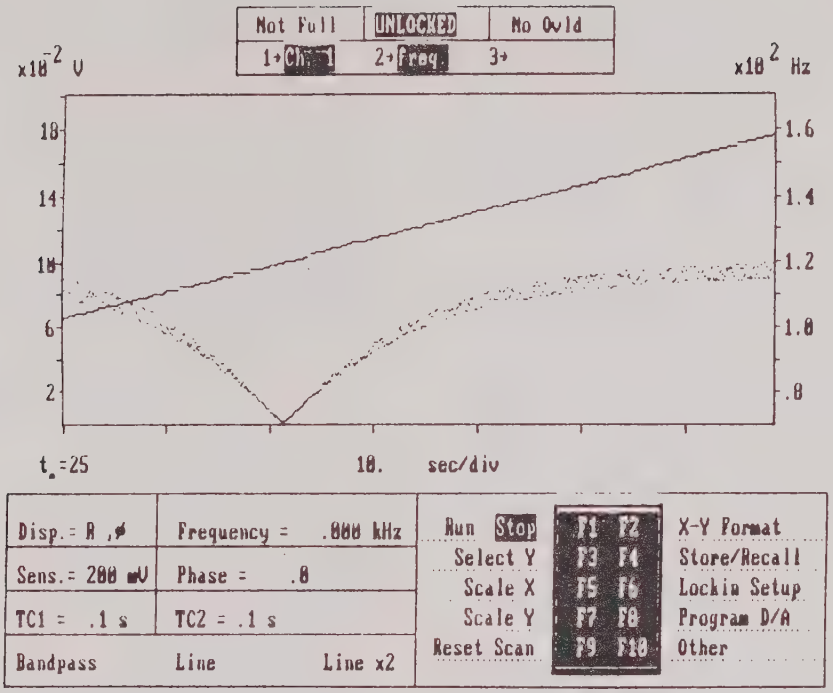
To plot the scan data in a form more suited for presentation, press F2 from the main menu. This causes the program to enter its other main mode of operation, the X-Y mode. The "X-Y mode" allows a full screen plot of any of the recorded quantities shown on the status bar vs. any other recorded quantitiy. Select the entire graph using the cursors which appear on the screen. Select frequency as the X-axis quantity and V as the Y-axis quantity. Select linear axes for both X and Y and select "yes" for both "Draw Grid?" and "Connect Points?" After a few seconds, you should see a full screen plot of lock-in output vs. frequency with labeled axes appearing on the monitor. The display should be similar to the one shown on page 58.

Note the cursor which appears on the title line of the display. You can move the cursor over the graph with the keypad arrow keys. Text typed at the keyboard appears on the screen at the cursor location.

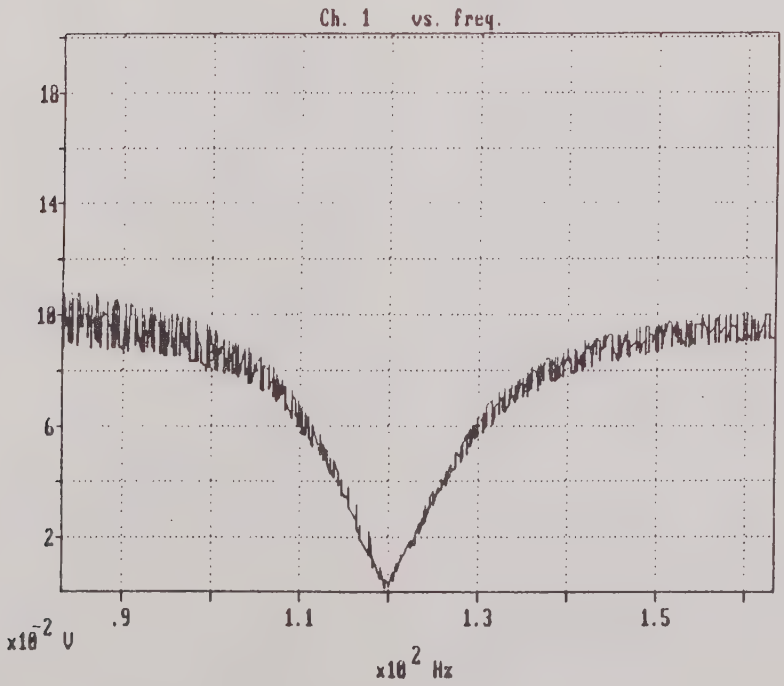
Now press F1. A pop-up menu will appear in the middle of the screen. Select F1 to smooth the data. The noise in the original data is due to the short time constant which was used while acquiring the data. Select a 9 point smooth and press <CR>. The plot will be smoothed and replotted. Now select F4. The Y-axis will be automatically scaled to reflect the range of Y values plotted on the screen. If you have an Epson-type

printer connected to your computer type <PrtSc> 2 to get a dump of the screen on your printer. (Note that <PrtSc> is a single shifted character) Finally, type <Esc> to remove the pop-up menu and <Esc> again to return to the main display screen.

The preceding example has just scratched the surface of the possible operations that can be performed with the SR575. For instance, you can fit lines and exponential curves to the data in the X-Y display by selecting F2 from the pop-up menu. Take a while now to explore through the menus and experiment with different selections.



Stripchart Mode (above), and X-Y mode (below) displays of data from the example measurement.



SR575 Reference Guide

General

The SR575 is the data acquisition program for the Stanford Research Systems SR530 Lock-in Amplifier. About 70% of the program is written in Microsoft FORTRAN, version 3.3. The remainder of the program is written in Intel 8086 Assembly Language. The program is designed to be run with the following hardware configurations:

IBM PC-AT or Compatible with
or without 80287 Numeric
Coprocessor.

IBM PC or PC/XT or Compatible with
8087 Numeric Coprocessor

In addition, the program will run, although performance will be sacrificed, with the following hardware configuration:

IBM PC or PC/XT or Compatible without
8087 Numeric Coprocessor

In all cases, at least 320 Kbytes of memory must be installed and the display must be a 720X348 monochrome adapter.

The Program Disk

The disk you received contains the following files:

SR575.EXE: SR575 program for use on machines without a numeric coprocessor.

SR575.887: SR575 program for use on machines with a numeric coprocessor.

SR575.CFG: Configuration file for SR575 program. Contains information about communications hardware. (Comes Configured in demo mode)

SR5CON.EXE: Program for configuring the SR575 for different communication setups.

NOTCH.L2A: Lock-in setup file containing front panel settings for the example measurement.

NOTCH.L2D: Data file containing results of the example measurement.

HGC.EXE: Program for initializing the monochrome graphics board in the "full" mode. (Running this program may not be necessary depending on the specific graphics card you use)

VIDEO.COM: Installs extended graphics drivers utilized by the SR575

PRNSRS.COM: Installs drivers to allow screen dump of program graphics to Epson-type printers.

PRNSRS.DEF: Contains data used by the PRNSRS program.

The SR575.CFG file on the program disk configures in a special demonstration mode that allows the program to be run without an SR530 lock-in amplifier. **You must run SR5CON.EXE and specify the communications hardware to create a new .CFG file before the program will run with an SR530.**

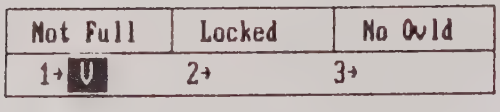
Using the SR575

The SR575 has two major operating modes, the stripchart mode and the X-Y mode. Data is first acquired as a function of time in the stripchart mode. In this mode, the program resembles an electronic stripchart recorder. The X-Y mode is used to generate full screen plots of the data acquired in the stripchart mode. Both operating modes contain powerful tools for manipulating both the data and the display.

The program is menu driven and has been designed so that it can be operated almost entirely from the function keys F1-F10 and from the numeric keypad on the IBM keyboard. Actual typing of text has been kept to a minimum. Selections of program items are made either by pressing the appropriate function key or moving a cursor with the arrow keys over the item to be selected and typing <CR> to confirm the selection. (The NumLock key must be **off** when the program is running to allow the numeric keypad to function as cursor control keys) The <Esc> key is used to exit the current function and move back through the tree of menus in the direction of the main menu.

The Stripchart Mode

The stripchart-mode display contains the status bar, the stripchart display, the virtual front panel, and the menu area. To dump the contents of the stripchart display to an Epson-type printer, type <PrtSc> 1.



The **status bar**, at the top of the display, has two lines. The top line has three status indicators. The first indicates whether the SR575 has reached its memory capacity of 4000 points/array. If so, the indicator will display "FULL." No further data acquisition is allowed once the arrays are full. The second indicates whether the SR530 is locked to the reference input. The third indicates whether the SR530 is in an overload condition.

The second line of the status bar displays which lock-in functions are currently being recorded by the SR575. Each function is shown next to the array number to which it corresponds. If a function is currently plotted on the stripchart display it is shown on the status bar in reverse video.

The **stripchart display**, in the center of the screen, is the area in which data from the SR530 is plotted. Up to two lock-in functions may be plotted on the stripchart display at once. Plotting a function involves pressing the key on the keypad corresponding to the array number of that function.

The amount of time plotted accross the stripchart display is variable from 10 seconds to 4500 seconds. This is controlled from the "Scale X" menu discussed below. If data acquisition lasts longer than this time, the display will scroll off to the left and new points will be plotted at the right edge of the graph. No data is lost when the display begins to scroll.

The most important lock-in front panel settings can be viewed on the **virtual front panel**, at the bottom left of the screen. This display is constantly updated to reflect the current lock-in front panel settings. The three SR530 signal filters at the bottom of the display are shown in reverse video when on, and in standard video when off. The front panel settings can be changed through the virtual front panel using the "Lock-in Setup" selection described below.

The stripchart mode has two major **menus**, both of which appear in the menu area at the bottom right of the screen. These are the "main" menu and the "other" menu. In the following section, the funtions of each menu selection are explained in detail.

Main Menu Functions

F1 Key (Run/Stop): The F1 key is used to start and stop data acquisition. The current Run/Stop status of the program is shown in reverse video on the main menu.

F3 Key (Select Y): The F3 key is used to select which values will be recorded by the program when data acquisiton begins. The SR575 has three data "arrays" into which data from the SR530 is placed. Each array has room for 4000 data points. Each of the arrays is associated with a particular lock-in function such as output, frequency, A/D voltage, etc.. When F3 is pressed, the program displays the 10 possible function choices in the menu area. They are:

Ch.1	Value Displayed on the Channel 1 output of the SR530.
Ch.2	Value Displayed on the Channel 2 output of the SR530
X	X output of the SR530
Y	Y output of the SR530
freq.	Frequency of the Reference Input.
X1-6	Voltage at the 6 general purpose D/As and A/Ds found on the back panel of the SR530.

Note the the data acquired when either "Ch.1" or "Ch.2" is selected depends on the display setting of the SR530. The display setting may be viewed and changed from the virtual front panel.

Up to three functions may be selected at one time. A function is selected by moving the cursor arrow over it and using the up or down arrow on the keypad to turn it on and off. When you are finished selecting, press <CR> to confirm the selections. The functions you have picked will appear on the status bar next to their corresponding array number indicating that they are being recorded. This does not imply that the function is currently being plotted on the stripchart display. To plot a function press the number on the keypad corresponding to the array number of the desired function. The function will now appear on the status bar in reverse video indicating that it is being plotted. To turn it off, press the array number again.

F5 Key (Scale X): This key has two functions. The first allows you to select the amount of time plotted accross the screen on the stripchart display. This is done by moving the cursor over the appropriate value and pressing <CR>. An <Esc> at this point will take you back to the main menu. If you continue, you can select the data acquisition sampling rate by scrolling the value displayed with the cursor keys. The SR575 displays the sampling rate and the maximum time for which data can be acquired at that rate. Pressing F1 will cause the program to select a sampling rate based on the current time constant setting of the SR530. The program chooses the sampling rate that is most nearly equal to 5/(time constant).

There are a few situations where the SR575 will overide the user's selection of sampling rate or time window size. Although any time window may be selected when the program is not acquiring data, there is a minimum window size for each sampling rate that applies when the program is acquiring data. If you try to start taking data when the window is below this minimum the SR575 will rescale the time window and display a message notifying you that this has been done.

If for any reason the SR575 cannot acquire data at the rate entered in the F5 menu it will simply go as fast as it can. The actual times associated with data points may always be read off with the cursor. (See the discussion of the cursor function)

F7 (Scale Y): This menu allows you to scale the Y values displayed on the stripchart display. If there are two arrays currently being plotted, the program will ask you to select which one you wish to scale. Use the arrow keys to move the blinking cursor on the status bar over the array you wish to scale. The minimum and maximum displayed values for that array will appear in the menu area. Two scaling options are allowed. Pressing F2 will allow you to explicitly enter the minimum and maximum values for that array. Pressing F1 "autoscales" the graph. That is, it scans the data plotted on the screen and adjusts the Y-axis scaling to appropriately display the data.

The up and down arrow keys are used in the scaling menu to "zoom" the Y axis. Pressing the down-arrow key zooms <u>in</u> on the Y axis while pressing the up-arrow key zooms <u>out</u>.

The units and multiplier for each array are shown above the axis corresponding to that array. In addition, The SR575 will sometimes display the message "Origin = <value>" above the axis. This will occur, for instance if you select 1.0 for Y minimum and 1.00001 for Y maximum. Since there is not enough room on the screen to display "1.00001" The program will label the axis in units of 10^{-6} and display the message "Origin = 1.0". The actual Y value is the sum of the origin value and the value displayed on the Y axis.

F9 (Reset Scan): Pressing F9 stops any data acquisition that may be in progress, clears all the data arrays and resets all D/A scans to their initial values.

F2 (X-Y Format): This selection allows you to enter the parameters for displaying data in the full-screen X-Y mode. X-Y mode enables you to generate a plot of any of the arrays recorded on the strip-chart display vs. any other array. In addition, time may be chosen as the X-axis for the X-Y mode display. When F2 is pressed, the SR575 will first replot the stripchart display so that the entire scan fits across the screen. The program then asks the following questions:

<u>Select Left/Right Hand Side of Region:</u>
Use the cursor control keys to select the portion of the stripchart display you want plotted in X-Y format. Pressing the <Home> key causes the cursor to move to the far left of the screen while <PgUp> moves the cursor to the far right.

<u>Select X/Y-axis quantity:</u>
Using the cursor, select the arrays you want plotted on the X and Y axes of the X-Y mode display.

<u>X/Y axis is Log/Linear:</u>
Either axis may be scaled linearly or logarithmically. Since non-positive values may not be displayed on logarithmic axes the SR575 will override the users selection of logarithmic axes if non-positive values are found in the array.

<u>Draw Grid:</u>
Selecting "yes" causes the SR575 to generate a coordinate grid on the X-Y plot. Selecting "no" suppresses the grid.

<u>Connect Points:</u>
Selecting "yes" causes the program to draw a line between points plotted in the X-Y format. Selecting "no" causes points to be plotted without connecting lines.

If something other than time has been chosen as the X-axis of the plot, the program must sort the X-axis array in order of increasing X-value before entering the X-Y mode. (In the stripchart mode, of course, the array is in order of increasing time)

Depending on the computer being used and the length of the array this process may take a few minutes. A "thermometer" will appear in the menu area to indicate the progress of the sort.

The message "Type F1 for menu" is a reminder that the pop-up menu can be summoned in the X-Y mode by pressing the F1 key.

F4 (Store/Recall): This selection allows you to store and recall data files from disk. There are two types of disk files used by the SR575. Lock-in Data files, which have the extension ".L2D", contain the data arrays acquired in the stripchart mode. In addition, ".L2D" files contain program setup information such as axis scaling and D/A scan parameters. Lock-in Amplifier files, which have the extension ".L2A", store a set of lock-in front panel settings. The Store/Recall menu allows you to access **data** files. Lock-in setup files are recalled from the F6 menu. (see below)

To recall a data file, press the F1 key. The SR575 will prompt you for a file name. Type the file name at the prompt preceded by an optional drive specifier. Do not type the extension ".L2D" as the SR575 automatically assumes this extension for data files. If you do not include a drive specifier, the program assumes the default disk drive. The default disk drive is initially set with the SR5CON program. If you do include a drive name, that drive becomes the default disk drive for all subsequent disk operations.

If you ask to recall a file when data is already present on the stripchart display the SR575 will ask you if you want to recall the entire file or a single array from the file. Pressing <CR> will cause the data currently recorded to be overwritten by the data from the file. Typing F1 allows you to read in a single array from the target file that will be displayed along with the current data. The SR575 will first prompt you for which array in the target file you wish to recall. It will then read that array into an empty array in the current display. (The new array will be given the name "Temp1" on the status bar) If there are no empty arrays the program will display a message asking you to free an array using the "Select Y" menu. The data is read in on a point-by-point basis, without any regard for the time scaling of the current display or the data in the file. Therefore, if the current data and the file data were taken with different sampling rates the resulting display is not necessarily meaningful.

To save the data on the stripchart display, enter the Store/Recall menu and press the F3 key. The program will prompt you for a filename. After a name is entered the SR575 will display a message confirming that the file has been successfully saved.

You can generate a catalog of ".L2D" files on the default disk drive by pressing the F2 key while in the Store/Recall menu. Each file will appear in the menu area along with the date and time it was saved. You can scroll through the catalog using the up and down arrow keys on the keypad. To recall the currently displayed file, simply press F1.

F6 (Lock-in Setup): The lock-in setup menu allows you to change the front-panel settings of the SR530 through the virtual front panel on the computer screen. To change a setting, move the cursor next to the desired quantity with the arrow keys. Next, scroll through the allowed values of the selected quantity with the up and down arrow keys. The SR575 will send the appropriate commands to the lock-in to set the new values.

Note that the virtual front panel will also reflect any changes made at the SR530. The SR575 is constantly interrogating the SR530's front panel settings and updating the virtual front panel to reflect any changes. The update rate varies depending on the current workload of the program but in no case will it be more than 4 or 5 seconds between the time a front-panel setting is changed and the time the change appears on the virtual front panel.

When phase is selected there are additional keys you can use to adjust the front-panel setting. <Home> will zero the phase. <PgUp> will increase the phase by 90°. <PgDn> will decrease the phase by 90°.

The Lock-in Setup menu also enables you to access ".L2A" files. ".L2A" files allow you to store an entire set of lock-in front panel settings and recall them at once. To use a ".L2A" file enter the lock-in setup menu and press the F1 key. You can store the current front panel settings with the F2 key or recall an existing file of settings with the F1 key. In either case, the SR575 will prompt you to enter a filename. The same remarks apply for entering ".L2A" filenames as did for data files.

F8 (Program D/A): This menu selection allows you to program either of the SR530's rear panel D/A outputs (X5 or X6) for a linear or exponential voltage ramp. The program first asks which D/A you wish to program. The program next asks you to set the initial and final voltages in the ramp. Note that the program will actually set the D/A voltage to the value displayed on the screen. Thus, if you are using the D/A to drive the VCO input of the internal oscillator, for instance, you can

watch the oscillator frequency change on the virtual front panel as you set the voltages for the ramp. The SR575 will then ask the following questions:

Enter Ramp Time: Enter the duration of the ramp in seconds. Typing <CR> causes the ramp time to default to the value shown on the screen.

Repeat or Single: "Repeat" causes the ramp to restart each time it reaches its final voltage. Selecting "Single" causes the ramp to terminate, and will turn off data acquisiton, after reaching its final voltage. In either case, the scan is reinitialized each time "Reset Scan" (F9) is selected from the main menu.

Linear or Log: Selecting "Linear" causes the voltage to ramp in a linear fashion. Selecting "Log" causes the voltage to ramp according to the equation:

$$V(t) = V_0 e^{kt}$$

where k is determined by:

$$k = (\ln(V_f/V_0))/\Delta t)$$

If a log scan is chosen, both the initial and final voltages must be positive. The SR575 will display an error message if this is not the case.

Pressing the F1 key in the Program D/A menu turns off the selected D/A scan. The scan will remain inactive until it is reprogramed.

F10 (Other): Pressing F10 causes the menu area to display the "other" menu rather than the main menu. The description of the "other" menu items are given below.

"Other" Menu

F1 (Smooth): Typing F1 in the "other" menu allows you to smooth data on the stripchart display. After selecting which array you want to smooth by moving the cursor on the status bar, the program will ask you whether you want a 3-point or 9-point smooth. The smoothing coefficients for the 3-point smooth are .25, .5, .25. For the 9-point smooth, the coefficients are .04, .08, .12, .16, .20, .16, .12, .08, .04. Select the appropriate smoothing method with the cursor and press <CR>. The program will smooth and replot the entire array, not just the portion visible on the screen.

F2 (Printer): Selecting Printer causes the SR575 to plot the contents of the stripchart arrays on an Epson type printer. All of the data will be plotted, not just the portion visible on the screen. To abort the plot type <Esc>.

F3 (Calculator): The calculator is a powerful tool which allows a wide range of arithmetic manipulations to be performed on data acquired in the stripchart mode. First select the array you wish to work on. It is important to remember that operations with the calculator will alter the data values stored in the selected array. Therefore, be sure to save any important data before changing it with the calculator. When an array has been changed with the calculator a "*"character appears next to it on the status bar to remind you that it has been changed.

Next select the operation you wish to perform on the array with the cursor. The operations "+", "-", "x", and "/" require two operands and you will be prompted for a second operand. Typing a constant at the cursor makes the second operand a constant with the specified value. Typing <CR> allows you to select an array from the status bar to be used as the second operand. Values in the second array are not changed, only the values in the first selected array are changed to reflect the results of the calculation. Note that the calculator operates on the entire data array; not just the portion of the data displayed on the screen.

The calculator ignores any data points that would result in illegal operations, such as taking the square root of a negative number, or dividing by 0.

Pressing F4 in the calculator autoscales the selected graph just as in the F7 Scale Y menu. This is included as it is often convenient to autoscale a graph after some calculator operation has been performed on it.

F4 (Copy): This selection allows you to copy the contents of an array into an empty array. The new array will be given the name "Temp1" (or "Temp2" if Temp1 is already taken). This function can be used with the caluclator to produce a variety of different functions. For instance, suppose you wanted to take the square root of an array and add it to itself. Copy the array using the F4 key to the array Temp1. Select the array in the calculator and take its square root. Now use the calculator to add the resultant array to the Temp1 array which you copied. The result will be in the original array while the Temp1 array will contain an untouched copy of the original data.

Temp arrays created by the Copy command are cleared by selecting "Reset Scan" or "Select Y Values" from the main menu.

F5 (<y>, $\sqrt{<\Delta y^2>}$): This function computes the mean and the rms variance of the data over a selected range. After choosing an array, a set of cursors allow you choose the range over which the values will be calculated. The mean and variance of the data in the selected array are then displayed in the menu area.

F6 (Cursor): Selecting F6 in the "other" menu puts a cursor up on the stripchart display and displays a readout of the X and Y values corresponding to the the cursor position in the menu area. The cursor menu can also be used to change the data in the arrays. Simply move the cursor to the desired position, press the F1 key, and enter the new value for the data point.

F7 (Autogain): The autogain feature reads the lock-in output and automatically adjusts the gain of the SR530 so that the signal is 20%-60% of full scale.

F8 (Exit to DOS): This selection terminates the program and returns you to DOS.

X-Y Mode Features

The Cursor: When the program enters the X-Y mode, a cursor is displayed which allows you to enter text onto the display at the cursor point. The cursor can be moved over the screen with the arrow keys on the keypad. The Pg Up key causes the cursor to move up to the title line at the top of the display. The Pg Dn key causes the cursor to move to the bottom of the display. To remove the cursor in order to plot a clean copy of the display, simply move it off the top or bottom of the screen.

Printing the Display: To dump a copy of the X-Y mode screen to an Epson-type printer type the single shifted character <PrtSc> followed by a "2". (Use the "2" on the keyboard, not the numerical pad.)

Exiting the X-Y mode: To exit the X-Y mode and return to the stripchart display type <Esc> when the popup menu is not present on the screen.

Pop-up menu: To summon the popup menu press the F1 key. The menu will appear in the center of the display. The various pop-up menu features are detailed below. To make the menu disappear, type <Esc> .

F1 (Smooth): This function has exactly the same function as it does in the stripchart mode. The only difference is that only the portion of the array selected with the cursors when X-Y mode was entered will be smoothed, the rest of the array will be unchanged. In general, operations performed in the X-Y mode only affect the portion of the array that was originally selected when the X-Y mode was entered.

F2 (Fit): The F2 selection in the pop-up menu allows you to generate exponential and linear fits to the data displayed in the X-Y mode. You first select a linear or exponential fit. The program will then ask you to select the region of data on the screen that you want to fit. After a few seconds, the program will draw the fitted curve on the display and display the fit parameters in the pop-up menu area. To remove the display of the fit parameters type <Esc>.

Note that for linear fits, the equation for the fitted line is referenced to the point X=0. For exponential fits, however the equation is referenced to the X-value corresponding to the leftmost point in the region selected to be fit.

The linear fit is a standard least squares fit. The exponential fit, however, is slightly more complex and works as follows. The program first does a linear fit to the the set of points $(x_i,\log(y_i))$ in the selected region and generates a preliminary estimate of the exponential decay constant. If this preliminary fit yields a rising exponential, then the program does another linear fit, this time only including data points that lie within 2.5 decay constants of right-hand edge of the fitted region. If the preliminary estimate yields a decaying exponential the program refits the data with a special fit that weights each data point by $1/x_i$ and only includes points within 2.5 preliminary decay constants of the left hand edge of the fitted region. The effect of this is to minimize the error caused by long exponential tails on the estimate of the exponential decay constant. If there are less than two data points within 2.5 preliminary time constants of the appropriate edge, the program displays an error message and terminates the fit.

Note that when the the program does a linear fit, it fits the same equation to the data points regardless of the way the data is being plotted. Thus, a linear fit will not appear to generate a straight line when plotted on a semilog plot.

F3 (Calculator): The calculator functions the same way as in the stripchart mode with three exceptions. First, only the portion of the array

selected with the cursors when X-Y mode was entered will be affected by operations in the calculator. Secondly, the second operand for "+", "-", "*", and "/" may only be a constant; you cannot operate on data with the X-Y mode calculator. Lastly, if the X-axis is anything besides time, the calculator will offer you the choice of operating on either the X-axis array or the Y-axis array. Pressing the F4 key in the calculator then autoscales either the X or Y axis depending on what you have selected.

If the results of a calculator operation are negative for an array that is being displayed on logarithmic axes, the program will display and error message and change to linear axes for that array.

F4 (Autoscale): This function autoscales the Y-axis. Autoscale functions just as it does in the "Scale Y" menu ot the stripchart display.

Alt-<arrow key> (Zoom, Translate): Pressing one of the arrow keys on the keypad while the pop-up menu is displayed causes the data on the display to shift in the direction of the arrow. This is useful, for instance, in centering an important feature on the display. Holding down the <Alt> key while pressing down an arrow key causes the display boundaries to expand or contract in the direction of the arrows. This can be used to "zoom in" on a feature on the display.

Format of ".L2D" Files

You may wish to write programs outside of the SR575 which use the data files written by the SR575. ".L2D" files are unformatted, binary, sequential files. They are **not** ASCII files. In the following description, only information relevant to recovering the data arrays from the files is given. The file contains other information used internally by the SR575. The type designation I2 refers to 2 byte integers, I4 to 4 byte integers, and R4 to 4 byte IEEE floating point numbers. The structure of ".L2D" files is as follows.

Variable	Type	Description
nbin	I2	1+number of points in each array
nrcrd	I2	number of arrays recorded in file
func(1)	I2	function of first array
func(2)	I2	function of second array
func(3)	I2	function of third array
	:	
	:	
174 bytes of information used internally by the SR575		
	:	
	:	
	:	
array 1	R4	first data array
array 2	R4	second data array
array 3	R4	third data array
timer	I4	timing array
EOF		

Only the number of data arrays given by nrcrd are in the file. The timing array is always in the file.

The function codes have the following meanings:

Code	Array Function
1	Ch.1
2	Ch.2
3	X
4	Y
5	frequency
6	X1
.	
.	
.	
11	X6
12	Null
13	Temp1
14	Temp 2

The timing array is an array of 4 byte integers. Each integer gives the time since the beginning of the scan of the corresponding data points in units of .0549254 seconds. (This number is the period of the PC's internal clock).

Source Code

The complete source code for the SR575 is available from Stanford Research Systems. The source code disk also contains a brief guide on how to modify the program to include custom features.

Addendum for GPIB Users

When using the SR575 with the Capital Equipment Corporation Interface card, make sure that the switch pointer on the card points to the "C" position. (See Appedndix E of the CEC manual) This sets the starting memory address used by the card to the value required by the SR575.

When using the SR575 with the National Instruments GPIB card, make sure you have the newer model PC2A card. The SR575 will not work with the model PC2 card. Also make sure that the starting I/O address has been set with IBCONF to 02E1h. The device name corresponding to the SR530 GPIB address must also be set to 'lockin' with the IBCONF program. Finally, you must use IBCONF to make sure that the EOS character for the lock-in is a line-feed (0Ah), not a carriage return.

Documentation

This section contains parts lists, PCB component placement diagrams, and schematics for the SR530 lock-in amplifier.

The first digit of any part number can be used to locate the schematic diagram for the part. For example, R415 is located on sheet 4 of the schematic diagrams.

The parts list also can be used to locate the part on the printed circuit board. The PCB is divided into one square inch areas which are labled by a digit and a letter. These digits and letters can be seen on the component silkscreen on the PCB. Parts with 4 digit part numbers are found on the quadrature detector plug-in board.

Main Circuit Board Parts List

REF NO	LOC	VALUE	DESCRIPTION
BR1	J12	BR-81D	INTEGRATED CIRCUIT
BATT1	O10	BR-2/3A	BATTERY/HOLDER
BR2	K12	BR-81D	INTEGRATED CIRCUIT
CY1	D12	4M	CRYSTAL
C101	A1	.1U	CAPACITOR, MYLAR/POLY, 50V, 5%, RADIAL
C102	A1	.1U	CAPACITOR, MYLAR/POLY, 50V, 5%, RADIAL
C103	A3	10U	CE
C104	A3	22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C105	A2	100P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C106	A2	22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C107	A2	2200U	CE
C108	A3	2200U	CE
C110	B1	10U	CE
C111	B1	1P	CAPACITOR, SILVER MICA, 250V, 5%, DM15
C116	B3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C117	B4	47U	CEEEA
C118	B4	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C120	A3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C121	A4	47U	CEEEA
C122	A3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C123	A4	1.0U	CAPACITOR, STACKED METAL FILM
C124	A4	1.0U	CAPACITOR, STACKED METAL FILM
C125	A5	2200U	CE
C126	A5	2200U	CE
C127	A5	.22U	CAPACITOR, STACKED METAL FILM
C128	A5	.22U	CAPACITOR, STACKED METAL FILM
C129	B10	1.0U	CAPACITOR, STACKED METAL FILM
C131	A10	1.0U	CAPACITOR, STACKED METAL FILM
C132	A13	1.0U	CAPACITOR, STACKED METAL FILM
C133	A6	.01U	CAPACITOR, STACKED METAL FILM
C134	A6	.01U	CAPACITOR, STACKED METAL FILM
C136	B4	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C137	B6	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C145	A7	24P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C146	A12	24P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C147	B13	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C148	B2	47P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C201	A7	7.5P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C202	A8	150P	CYHCB
C203	A8	.0015U	CAPACITOR, STACKED METAL FILM
C204	A8	.015U	CAPACITOR, STACKED METAL FILM
C205	A8	.15U	CAPACITOR, STACKED METAL FILM
C206	B9	1.0U	CAPACITOR, STACKED METAL FILM
C207	B9	.47U	CAPACITOR, STACKED METAL FILM
C208	A7	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C209	A9	150P	CYHCB
C210	A10	.0015U	CAPACITOR, STACKED METAL FILM
C211	A10	.015U	CAPACITOR, STACKED METAL FILM
C212	A9	.15U	CAPACITOR, STACKED METAL FILM
C213	A10	1.0U	CAPACITOR, STACKED METAL FILM
C214	A10	.47U	CAPACITOR, STACKED METAL FILM
C215	B8	1.0U	CAPACITOR, STACKED METAL FILM
C216	A12	.1U	CAPACITOR, STACKED METAL FILM
C217	A14	10U	CE
C218	A14	10U	CE
C230	A8	.15U	CAPACITOR, STACKED METAL FILM
C301	O2	1.0U	CAPACITOR, STACKED METAL FILM
C302	O4	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C303	O4	24P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C304	O5	560P	CYHCB
C305	O5	10U	CE
C306	N3	1.0U	CAPACITOR, STACKED METAL FILM
C307	N3	.001U	CAPACITOR, STACKED METAL FILM
C308	N2	.33U	CAPACITOR, STACKED METAL FILM
C309	N4	DELETE	CAPACITOR, STACKED METAL FILM
C310	N2	22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C311	L2	22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C312	N2	47P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C313	K2	47P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C314	L6	.1U	CAPACITOR, STACKED METAL FILM
C315	L3	10U	CE
C317	M5	1.0U	CAPACITOR, STACKED METAL FILM
C318	L5	.001U	CAPACITOR, STACKED METAL FILM
C319	L5	.33U	CAPACITOR, STACKED METAL FILM
C320	M3	.001U	CAPACITOR, STACKED METAL FILM
C321	L5	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C322	K4	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C323	O6	47U	CEEEA
C324	O6	47U	CEEEA
C325	O3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C326	O2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C327	K3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C328	K2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C329	O6	47U	CE
C330	O3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C331	L2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C332	K3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C333	K2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C334	N2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C335	M3	470P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C336	O5	470P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C337	L2	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C338	L3	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C401	G2	1.0U	CAPACITOR, STACKED METAL FILM
C402	F2	.01U	CAPACITOR, STACKED METAL FILM
C403	G2	.01U	CAPACITOR, STACKED METAL FILM
C404	D2	1.0U	CAPACITOR, STACKED METAL FILM
C405	D2	1.0U	CAPACITOR, STACKED METAL FILM
C406	C3	.01U	CAPACITOR, STACKED METAL FILM
C407	C3	.01U	CAPACITOR, STACKED METAL FILM
C408	D3	10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C409	E3	.1U	CAPACITOR, STACKED METAL FILM
C410	E3	.1U	CAPACITOR, STACKED METAL FILM
C411	E4	.1U	CAPACITOR, STACKED METAL FILM
C412	F3	.1U	CAPACITOR, STACKED METAL FILM
C413	H3	.001U	CAPACITOR, STACKED METAL FILM
C414	F3	.033U	CAPACITOR, STACKED METAL FILM
C415	G4	10U	CAPACITOR, MYLAR/POLY, 50V, 5%, RADIAL
C416	F4	.1U	CAPACITOR, STACKED METAL FILM
C417	F4	1.0U	CAPACITOR, STACKED METAL FILM
C418	C4	.01U	CAPACITOR, STACKED METAL FILM
C419	C4	.01U	CAPACITOR, STACKED METAL FILM
C420	E3	.001U	CAPACITOR, STACKED METAL FILM
C421	E4	33P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C422	F4	33P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C501	E7	330P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C502	D6	.0047U	CAPACITOR, POLYSTYRENE, 50V, 5%, RADIAL
C503	E5	220P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C504	I6	100P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C505	F7	22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C506	H7	.047U	CAPACITOR, STACKED METAL FILM
C507	H6	.047U	CAPACITOR, STACKED METAL FILM
C508	H6	.047U	CAPACITOR, STACKED METAL FILM
C509	H6	.047U	CAPACITOR, STACKED METAL FILM
C510	H6	.047U	CAPACITOR, STACKED METAL FILM
C511	H7	.047U	CAPACITOR, STACKED METAL FILM
C512	H7	.047U	CAPACITOR, STACKED METAL FILM
C513	H7	.047U	CAPACITOR, STACKED METAL FILM
C514	H6	.001U	CAPACITOR, STACKED METAL FILM
C515	H5	.001U	CAPACITOR, STACKED METAL FILM
C516	H6	.001U	CAPACITOR, STACKED METAL FILM
C517	D6	100P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C518	D4	.1U	CAPACITOR, STACKED METAL FILM
C519	E6	.001U	CAPACITOR, STACKED METAL FILM
C520	C5	.01U	CAPACITOR, STACKED METAL FILM
C521	C5	.01U	CAPACITOR, STACKED METAL FILM
C523	E7	.01U	CAPACITOR, STACKED METAL FILM
C525	C5	.01U	CAPACITOR, STACKED METAL FILM
C526		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C527		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U

REF NO	LOC	VALUE	DESCRIPTION
C701	D12	220P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C702	D12	220P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C703	J6	1U	CAPACITOR, ELECTROLYTIC, 50V, 20%,RADIAL
C704	J7	1U	CAPACITOR, ELECTROLYTIC, 50V, 20%,RADIAL
C705	D9	.01U	CAPACITOR, STACKED METAL FILM
C706	N9	.01U	CAPACITOR, STACKED METAL FILM
C707	M7	.01U	CAPACITOR, STACKED METAL FILM
C708	D12	.01U	CAPACITOR, STACKED METAL FILM
C709	L12	.01U	CAPACITOR, STACKED METAL FILM
C710	L10	.01U	CAPACITOR, STACKED METAL FILM
C711	J9	.01U	CAPACITOR, STACKED METAL FILM
C712	F10	.01U	CAPACITOR, STACKED METAL FILM
CN801		9 PIN D	CONNECTOR
CB01	G15	330P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
CN802		RS232 F PC	CONNECTOR
CB02	H15	330P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
CN803		IEEE488 PC	CONNECTOR
CB03	H15	330P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
CB04	C15	.01U	CAPACITOR, STACKED METAL FILM
CB05	I14	.01U	CAPACITOR, STACKED METAL FILM
CB06	G14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
CB07	H14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
CB08	G14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
CB09	G14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C901	A15	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C902	A14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C903	D6	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C904	D6	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C905	C10	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C906	C10	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C907	A15	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C908	A15	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C909	D6	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C910	D6	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C911	C11	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C912	C10	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C913	C10	47U	CEEEA
C914	C11	47U	CEEEA
C915	C9	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C916	C9	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C917	C9	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C918	C9	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C919	A15	47U	CEEEA
C920	A15	47U	CEEEA
C923	F13	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C924	G14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C925	F11	2500U	CAPACITOR, ELECTROLYTIC, 50V, 20%, AXIAL
C926	F13	2500U	CAPACITOR, ELECTROLYTIC, 50V, 20%, AXIAL
C927	E13	1.0U	CTH
C928	E14	1.0U	CTH
C929	E13	100U	CEEEA
C930	E14	100U	CEEEA
C931	E12	100U	CEEEA
C932	F14	100U	CEEEA
C933	E12	1.0U	CTH
C934	E15	1.0U	CTH
C935	F10	7200U	CEEEB
C936	J12	.1U	CAPACITOR, STACKED METAL FILM
C937	K12	.1U	CAPACITOR, STACKED METAL FILM
C938	B14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C939	B14	2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
D101	B3	1N4148	DIODE
D102	B3	1N4148	DIODE
D103	B2	1N4148	DIODE
D104	B2	1N4148	DIODE
D105	B13	1N4148	DIODE
D106	B13	1N4148	DIODE
D201	B13	1N4148	DIODE
D202	B13	1N4148	DIODE
D203	A13	1N4148	DIODE

REF NO	LOC	VALUE	DESCRIPTION
D204	A13	1N4148	DIODE
D301	N6	1N4148	DIODE
D302	L3	1N4148	DIODE
D303	L5	1N4148	DIODE
D401	C4	1N4148	DIODE
D402	C4	1N4148	DIODE
D403	E5	1N4148	DIODE
D404	E5	1N4148	DIODE
D501	D5	1N4148	DIODE
D502	D5	1N4148	DIODE
D503	C6	1N4148	DIODE
D504	D5	1N4148	DIODE
D701	D9	1N747A	DIODE
D702	N9	1N4148	DIODE
D703	N9	1N4148	DIODE
D901	E13	1N4007	DIODE
D902	F13	1N4007	DIODE
D903	F15	1N4007	DIODE
D904	F15	1N4007	DIODE
FUSE		.5ASLO-BLO	FUSE
H1	E12	2 PIN DIF	CONNECTOR
H2	E15	2 PIN DIF	CONNECTOR
H3	G14	2 PIN DIF	CONNECTOR
J1		2 PIN DI	CONNECTOR
J2	E15	2 PIN DI	CONNECTOR
J3	G14	2 PIN DI	CONNECTOR
PCB1	OFF	SR500	PRINTED CIRCUIT BOARD
P101	A1	20	PCB MOUNT TRIM POT, INLINE LEADS, .1"
P102	A3	20K	POTENTIOMETER, MUTLI-TURN TRIM
P103	A4	20K	POTENTIOMETER, MUTLI-TURN TRIM
P104	B5	50K	POTENTIOMETER, MUTLI-TURN TRIM
P105	B5	5K	POTENTIOMETER, MUTLI-TURN TRIM
P401	G3	10K	POTENTIOMETER, MUTLI-TURN TRIM
P402	D2	10K	POTENTIOMETER, MUTLI-TURN TRIM
P403	C2	10K	POTENTIOMETER, MUTLI-TURN TRIM
P404	F4	10K	POTENTIOMETER, MUTLI-TURN TRIM
P501	E7	100	PCB MOUNT TRIM POT, INLINE LEADS, .1"
P502	E6	100	PCB MOUNT TRIM POT, INLINE LEADS, .1"
Q101	A2	2N6485	TO-71
Q102	B1	2N6485	TO-71
Q103	B1	MPSA18	TRANSISTOR, TO-92 PACKAGE
Q201	A12	2N4249	TRANSISTOR, TO-92 PACKAGE
Q202	A9	2N5210	TRANSISTOR, TO-92 PACKAGE
Q502	H6	2N5210	TRANSISTOR, TO-92 PACKAGE
Q701	N9	2N5210	TRANSISTOR, TO-92 PACKAGE
Q702	K7	2N5210	TRANSISTOR, TO-92 PACKAGE
Q703	K6	2N5210	TRANSISTOR, TO-92 PACKAGE
R101	A1	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R102	A1	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R103	A1	10	RESISTOR, CARBON FILM, 1/4W, 5%
R104	A1	100	RESISTOR, CARBON FILM, 1/4W, 5%
R105	A1	100	RESISTOR, CARBON FILM, 1/4W, 5%
R108	A3	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R109	A2	6.81K	RESISTOR, METAL FILM, 1/8W, 1%
R110	A2	6.81K	RESISTOR, METAL FILM, 1/8W, 1%
R111	A1	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R112	A2	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R113	A2	110	RESISTOR, METAL FILM, 1/8W, 1%
R114	A2	110	RESISTOR, METAL FILM, 1/8W, 1%
R115	A1	2.2	RESISTOR, CARBON FILM, 1/4W, 5%
R116	A3	6.04K	RESISTOR, METAL FILM, 1/8W, 1%
R117	A3	9.09K	RESISTOR, METAL FILM, 1/8W, 1%
R118	A2	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R119	B3	499	RESISTOR, METAL FILM, 1/8W, 1%
R120	B3	301	RESISTOR, METAL FILM, 1/8W, 1%
R121	B3	100	RESISTOR, METAL FILM, 1/8W, 1%
R122	B3	100	RESISTOR, METAL FILM, 1/8W, 1%
R126	B2	9.09K	RESISTOR, METAL FILM, 1/8W, 1%
R127	B2	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R128	B1	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%

REF NO	LOC	VALUE	DESCRIPTION
R226	A13	6.8K	RESISTOR, CARBON FILM, 1/4W, 5%
R227	A13	3.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R228	A14	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R229	A14	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R301	O2	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R302	O3	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R303	O3	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R304	O4	2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R305	O4	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R306	O4	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R307	O4	13K	RESISTOR, CARBON FILM, 1/4W, 5%
R308	O5	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R309	O6	330K	RESISTOR, CARBON FILM, 1/4W, 5%
R310	N5	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R311	N4	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R312	N4	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R313	N5	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R314	N4	300K	RESISTOR, CARBON FILM, 1/4W, 5%
R315	N5	680K	RESISTOR, CARBON FILM, 1/4W, 5%
R316	N4	680K	RESISTOR, CARBON FILM, 1/4W, 5%
R317	N4	6.2K	RESISTOR, CARBON FILM, 1/4W, 5%
R318	N3	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R319	O2	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R320	N5	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R321	N5	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R322	N5	249K	RESISTOR, METAL FILM, 1/8W, 1%
R323	N4	6.81K	RESISTOR, METAL FILM, 1/8W, 1%
R324	N4	6.81K	RESISTOR, METAL FILM, 1/8W, 1%
R325	O2	2.80K	RESISTOR, METAL FILM, 1/8W, 1%
R326	K2	13.0K	RESISTOR, METAL FILM, 1/8W, 1%
R327	K2	2.10K	RESISTOR, METAL FILM, 1/8W, 1%
R328	N2	1.8K	RESISTOR, CARBON FILM, 1/4W, 5%
R329	N2	51K	RESISTOR, CARBON FILM, 1/4W, 5%
R330	N2	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R332	K2	2.49K	RESISTOR, METAL FILM, 1/8W, 1%
R333	L2	1.8K	RESISTOR, CARBON FILM, 1/4W, 5%
R334	K2	6.49K	RESISTOR, METAL FILM, 1/8W, 1%
R335	L2	51K	RESISTOR, CARBON FILM, 1/4W, 5%
R336	L2	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R337	O2	10M	RESISTOR, CARBON FILM, 1/4W, 5%
R338	O2	10	RESISTOR, CARBON FILM, 1/4W, 5%
R339	N6	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R340	L3	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R341	K6	1.2M	RESISTOR, CARBON FILM, 1/4W, 5%
R342	L4	330K	RESISTOR, CARBON FILM, 1/4W, 5%
R343	M5	2.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R344	M4	300K	RESISTOR, CARBON FILM, 1/4W, 5%
R345	M4	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R346	M3	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R347	M3	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R348	M3	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R349	M5	300K	RESISTOR, CARBON FILM, 1/4W, 5%
R350	M5	6.2K	RESISTOR, CARBON FILM, 1/4W, 5%
R351	M5	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R352	N6	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R353	N6	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R354	N5	75.0K	RESISTOR, METAL FILM, 1/8W, 1%
R355	M3	4.53K	RESISTOR, METAL FILM, 1/8W, 1%
R356	M3	2.26K	RESISTOR, METAL FILM, 1/8W, 1%
R357	M6	2.80K	RESISTOR, METAL FILM, 1/8W, 1%
R358	N6	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R359	L5	2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R360	L5	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R361	L5	5.1K	RESISTOR, CARBON FILM, 1/4W, 5%
R362	L6	32.4K	RESISTOR, METAL FILM, 1/8W, 1%
R363	L6	1.10K	RESISTOR, METAL FILM, 1/8W, 1%
R364	L4	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R365	L4	2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R366	L3	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R367	L6	130K	RESISTOR, METAL FILM, 1/8W, 1%

REF NO	LOC	VALUE	DESCRIPTION
R130	B2	470K	RESISTOR, CARBON FILM, 1/4W, 5%
R132	B1	470K	RESISTOR, CARBON FILM, 1/4W, 5%
R133	B2	30.1K	RESISTOR, METAL FILM, 1/8W, 1%
R134	B2	30.1K	RESISTOR, METAL FILM, 1/8W, 1%
R135	B1	1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R138	B4	20	RESISTOR, CARBON FILM, 1/4W, 5%
R139	A4	20	RESISTOR, CARBON FILM, 1/4W, 5%
R140	A5	13.0K	RESISTOR, METAL FILM, 1/8W, 1%
R141	A4	280	RESISTOR, METAL FILM, 1/8W, 1%
R142	A4	22.6K	RESISTOR, METAL FILM, 1/8W, 1%
R143	A4	13.0K	RESISTOR, METAL FILM, 1/8W, 1%
R144	B4	16.9K	RESISTOR, METAL FILM, 1/8W, 1%
R145	B4	16.9K	RESISTOR, METAL FILM, 1/8W, 1%
R146	B6	499	RESISTOR, METAL FILM, 1/8W, 1%
R147	B6	301	RESISTOR, METAL FILM, 1/8W, 1%
R148	B6	100	RESISTOR, METAL FILM, 1/8W, 1%
R149	B6	100	RESISTOR, METAL FILM, 1/8W, 1%
R150	A6	30.1K	RESISTOR, METAL FILM, 1/8W, 1%
R151	A5	634	RESISTOR, METAL FILM, 1/8W, 1%
R152	A5	54.9K	RESISTOR, METAL FILM, 1/8W, 1%
R153	A5	3.01K	RESISTOR, METAL FILM, 1/8W, 1%
R154	A6	3.83K	RESISTOR, METAL FILM, 1/8W, 1%
R155	A6	9.53K	RESISTOR, METAL FILM, 1/8W, 1%
R156	A6	499	RESISTOR, METAL FILM, 1/8W, 1%
R157	A6	301	RESISTOR, METAL FILM, 1/8W, 1%
R158	A6	100	RESISTOR, METAL FILM, 1/8W, 1%
R159	A6	100	RESISTOR, METAL FILM, 1/8W, 1%
R160	B10	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R161	B10	750	RESISTOR, METAL FILM, 1/8W, 1%
R162	B10	4.99K	RESISTOR, METAL FILM, 1/8W, 1%
R163	A10	10M	RESISTOR, CARBON FILM, 1/4W, 5%
R165	A11	909	RESISTOR, METAL FILM, 1/8W, 1%
R166	A11	100	RESISTOR, METAL FILM, 1/8W, 1%
R167	B11	909	RESISTOR, METAL FILM, 1/8W, 1%
R168	B11	100	RESISTOR, METAL FILM, 1/8W, 1%
R169	A11	1.24K	RESISTOR, METAL FILM, 1/8W, 1%
R170	A11	107	RESISTOR, METAL FILM, 1/8W, 1%
R171	A11	33.2	RESISTOR, METAL FILM, 1/8W, 1%
R172	A10	10M	RESISTOR, CARBON FILM, 1/4W, 5%
R173	A12	499	RESISTOR, METAL FILM, 1/8W, 1%
R174	A12	301	RESISTOR, METAL FILM, 1/8W, 1%
R175	B12	200	RESISTOR, METAL FILM, 1/8W, 1%
R176	A13	9.53K	RESISTOR, METAL FILM, 1/8W, 1%
R177	B13	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R178	A13	10M	RESISTOR, CARBON FILM, 1/4W, 5%
R201	B8	1.50K	RESISTOR, METAL FILM, 1/8W, 1%
R202	A7	5.11K	RESISTOR, METAL FILM, 1/8W, 1%
R203	B8	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R204	B8	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R205	B9	15.0K	RESISTOR, METAL FILM, 1/8W, 1%
R206	A7	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R207	A7	1.50K	RESISTOR, METAL FILM, 1/8W, 1%
R208	A7	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R209	A8	13.0K	RESISTOR, METAL FILM, 1/8W, 1%
R210	A8	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R211	A7	10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R212	A7	1.50K	RESISTOR, METAL FILM, 1/8W, 1%
R213	A7	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R214	A7	13.0K	RESISTOR, METAL FILM, 1/8W, 1%
R215	B9	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R216	A9	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R217	A9	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R218	B9	10M	RESISTOR, CARBON FILM, 1/4W, 5%
R219	A12	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R220	A12	3.48K	RESISTOR, METAL FILM, 1/8W, 1%
R221	A13	120K	RESISTOR, CARBON FILM, 1/4W, 5%
R222	A13	62K	RESISTOR, CARBON FILM, 1/4W, 5%
R223	A13	120K	RESISTOR, CARBON FILM, 1/4W, 5%
R224	A13	6.8K	RESISTOR, CARBON FILM, 1/4W, 5%
R225	A13	3.0K	RESISTOR, CARBON FILM, 1/4W, 5%

REF NO	LOC	VALUE	DESCRIPTION
R368	L6	16.2K	RESISTOR, METAL FILM, 1/8W, 1%
R369	L6	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R370	L6	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R371	Q6	10	RESISTOR, CARBON FILM, 1/4W, 5%
R372	Q2	1.1M	RESISTOR, CARBON FILM, 1/4W, 5%
R373	M5	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R374	M6	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R375	Q2	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R376	M3	100M	RESISTOR, CARBON FILM, 1/4W, 5%
R377	M3	4.53K	RESISTOR, METAL FILM, 1/8W, 1%
R378	Q2	2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
RN401	I2	8X10K	RESISTOR NETWORK, DIP, 1/4W, 2%, B INDEP
R401	H2	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R402	H2	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R403	G2	5.1M	RESISTOR, CARBON FILM, 1/4W, 5%
R404	F2	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R405	F2	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R406	F2	499	RESISTOR, METAL FILM, 1/8W, 1%
R407	D2	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R408	D2	1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R409	C2	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R410	D3	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R411	C3	499	RESISTOR, METAL FILM, 1/8W, 1%
R412	D3	1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R413	D3	75.0K	RESISTOR, METAL FILM, 1/8W, 1%
R414	D3	47	RESISTOR, CARBON FILM, 1/4W, 5%
R415	D3	100K	RESISTOR, METAL FILM, 1/8W, 1%
R417	E3	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R418	E3	1.10K	RESISTOR, METAL FILM, 1/8W, 1%
R419	F2	30.1K	RESISTOR, METAL FILM, 1/8W, 1%
R420	E3	348K	RESISTOR, METAL FILM, 1/8W, 1%
R421	H3	150K	RESISTOR, METAL FILM, 1/8W, 1%
R422	G3	37.4K	RESISTOR, METAL FILM, 1/8W, 1%
R423	F3	9.76K	RESISTOR, METAL FILM, 1/8W, 1%
R424	G3	2.49K	RESISTOR, METAL FILM, 1/8W, 1%
R425	H2	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R426	H3	2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R427	F4	1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R428	F4	1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R429	F4	110K	RESISTOR, METAL FILM, 1/8W, 1%
R430	F4	10.2K	RESISTOR, METAL FILM, 1/8W, 1%
R431	D3	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R432	E4	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R433	E4	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R501	D9	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R502	D9	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R503	D9	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R504	D9	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R505	D9	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R506	D9	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R507	D9	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R508	D9	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R509	D7	10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R510	D7	20.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R511	E6	10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R512	E6	20.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R513	D7	200K	RESISTOR, METAL FILM, 1/8W, 1%
R514	D6	806K	RESISTOR, METAL FILM, 1/8W, 1%
R515	E6	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R516	E6	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R518	E6	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R519	J6	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R520	E7	51	RESISTOR, CARBON FILM, 1/4W, 5%
R521	E6	51	RESISTOR, CARBON FILM, 1/4W, 5%
R522	E7	10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R523	E6	10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R524	F7	39K	RESISTOR, CARBON FILM, 1/4W, 5%
R525	F6	22K	RESISTOR, CARBON FILM, 1/4W, 5%
R526	F6	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R527	F6	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R528	E5	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R529	E5	220	RESISTOR, CARBON FILM, 1/4W, 5%
R530	F6	9.09K	RESISTOR, METAL FILM, 1/8W, 1%
R531	F6	1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R532	H7	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R533	H7	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R534	H5	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R535	H6	220	RESISTOR, CARBON FILM, 1/4W, 5%
R536	H5	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R537	H5	220	RESISTOR, CARBON FILM, 1/4W, 5%
R538	H6	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R539	H6	220	RESISTOR, CARBON FILM, 1/4W, 5%
R540	D6	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R541	D6	220	RESISTOR, CARBON FILM, 1/4W, 5%
R542	D4	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R543	D4	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R544	D4	15K	RESISTOR, CARBON FILM, 1/4W, 5%
R545	C4	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R546	C4	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R547	C4	15K	RESISTOR, CARBON FILM, 1/4W, 5%
R548	D4	200K	RESISTOR, CARBON FILM, 1/4W, 5%
R549	D4	100K	RESISTOR, CARBON FILM, 1/4W, 5%
R701	N9	100	RESISTOR, CARBON FILM, 1/4W, 5%
R702	O11	4.7K	RESISTOR, CARBON FILM, 1/4W, 5%
R703	N9	1.5K	RESISTOR, CARBON FILM, 1/4W, 5%
R705	O10	1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R706	O12	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R707	O12	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R708	J7	300K	RESISTOR, CARBON FILM, 1/4W, 5%
R709	J7	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R710	J7	1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R711	J7	10K	RESISTOR, CARBON FILM, 1/4W, 5%
RN801	C15	9X100K	RESISTOR NETWORK, SIP, 1/4W, 2%
R801	F15	10K	RESISTOR, CARBON FILM, 1/4W, 5%
R802	F15	10K	RESISTOR, CARBON FILM, 1/4W, 5%
RN802	D15	9X100K	RESISTOR NETWORK, SIP, 1/4W, 2%
R803	I14	3.3K	RESISTOR, CARBON FILM, 1/4W, 5%
R901	D10	10	RESISTOR, CARBON COMP, 1/2W, 5%
R902	D11	10	RESISTOR, CARBON COMP, 1/2W, 5%
R903	D9	240	RESISTOR, CARBON FILM, 1/4W, 5%
R904	D9	1.2K	RESISTOR, CARBON FILM, 1/4W, 5%
R905	D9	1.2K	RESISTOR, CARBON FILM, 1/4W, 5%
R906	D9	240	RESISTOR, CARBON FILM, 1/4W, 5%
R907	A15	10	RESISTOR, CARBON COMP, 1/2W, 5%
R908	A15	10	RESISTOR, CARBON COMP, 1/2W, 5%
R909	F12	200	RESISTOR, CARBON FILM, 1/4W, 5%
R910	F13	3.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R911	E14	3.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R912	F15	200	RESISTOR, CARBON FILM, 1/4W, 5%
R913	Q7	10	RESISTOR, CARBON COMP, 1/2W, 5%
R914	Q7	10	RESISTOR, CARBON COMP, 1/2W, 5%
SW1	D15	SPSTX8	DIP SWITCH, SIDE ACTUATED
SW2	D15	SPSTX8	DIP SWITCH, SIDE ACTUATED
SW601	A1	4PDT	SWORK
SO701	N10	40	IC SOCKET
SO702	N9	28	IC SOCKET
T1		2078A	TRANSFORMER
U101	A3	XR5533A	INTEGRATED CIRCUIT
U102	B2	XR5533A	INTEGRATED CIRCUIT
U103	B4	D6211	INTEGRATED CIRCUIT
U104	B4	MC78L15	INTEGRATED CIRCUIT
U105	A3	MC79L15	INTEGRATED CIRCUIT
U106	B7	D6211	INTEGRATED CIRCUIT
U107	A4	XR5532A	INTEGRATED CIRCUIT
U108	B5	D6211	INTEGRATED CIRCUIT
U109	A6	LF353	INTEGRATED CIRCUIT
U110	B6	D6211	INTEGRATED CIRCUIT
U111	B10	LF357	INTEGRATED CIRCUIT
U112	A11	D6211	INTEGRATED CIRCUIT
U113	A11	LF357	INTEGRATED CIRCUIT

REF NO	LOC	VALUE	DESCRIPTION
U114	B12	D6211	INTEGRATED CIRCUIT
U115	B13	LF357	INTEGRATED CIRCUIT
U117	A10	LF353	INTEGRATED CIRCUIT
U118	A5	XR5532A	INTEGRATED CIRCUIT
U201	B8	LF347	INTEGRATED CIRCUIT
U202	A8	LM13600	INTEGRATED CIRCUIT
U203	A8	CD4052	INTEGRATED CIRCUIT
U204	A9	CD4052	INTEGRATED CIRCUIT
U205	B9	D6211	INTEGRATED CIRCUIT
U206	B6	74HC139	INTEGRATED CIRCUIT
U207	B11	74HC139	INTEGRATED CIRCUIT
U208	A12	LF347	INTEGRATED CIRCUIT
U301	O3	LF353	INTEGRATED CIRCUIT
U303	O3	D6211	INTEGRATED CIRCUIT
U304	O4	LM311	INTEGRATED CIRCUIT
U305	O5	CD4538	INTEGRATED CIRCUIT
U306	O5	CD4046	INTEGRATED CIRCUIT
U307	O4	LM13600	INTEGRATED CIRCUIT
U308	O3	CA3140E	INTEGRATED CIRCUIT
U309	O2	LM13600	INTEGRATED CIRCUIT
U310	N3	D6211	INTEGRATED CIRCUIT
U311	N4	D6211	INTEGRATED CIRCUIT
U312	M2	D6211	INTEGRATED CIRCUIT
U313	M2	74HC74	INTEGRATED CIRCUIT
U314	N2	LM311	INTEGRATED CIRCUIT
U315	L2	LM311	INTEGRATED CIRCUIT
U316	M3	CD4046	INTEGRATED CIRCUIT
U317	M4	LM13600	INTEGRATED CIRCUIT
U318	L4	D6211	INTEGRATED CIRCUIT
U319	M5	CA3140E	INTEGRATED CIRCUIT
U320	M5	D6211	INTEGRATED CIRCUIT
U321	M6	CA3140E	INTEGRATED CIRCUIT
U322	M6	LM13600	INTEGRATED CIRCUIT
U323	N6	LM13600	INTEGRATED CIRCUIT
U324	L5	LM311	INTEGRATED CIRCUIT
U325	L6	LF412	INTEGRATED CIRCUIT
U326	J2	CD4018	INTEGRATED CIRCUIT
U327	L3	D6211	INTEGRATED CIRCUIT
U328	L4	LM311	INTEGRATED CIRCUIT
U329	L4	LM311	INTEGRATED CIRCUIT
U401	H2	D6211	INTEGRATED CIRCUIT
U402	H2	LF412	INTEGRATED CIRCUIT
U403	G2	LF411	INTEGRATED CIRCUIT
U404	F2	LT1007	INTEGRATED CIRCUIT
U405	E2	CD4066	INTEGRATED CIRCUIT
U406	E2	AD534	INTEGRATED CIRCUIT
U407	C2	LF411	INTEGRATED CIRCUIT
U408	D3	LT1007	INTEGRATED CIRCUIT
U409	D3	LF411	INTEGRATED CIRCUIT
U410	E3	ICL7650	INTEGRATED CIRCUIT
U411	H3	RELAY	INTEGRATED CIRCUIT
U412	G3	RELAY	INTEGRATED CIRCUIT
U413	F3	RELAY	INTEGRATED CIRCUIT
U414	G3	RELAY	INTEGRATED CIRCUIT
U415	H3	RELAY	INTEGRATED CIRCUIT
U416	F3	ICL7650	INTEGRATED CIRCUIT
U417	H4	RELAY	INTEGRATED CIRCUIT
U418	G4	D6211	INTEGRATED CIRCUIT
U419	E4	LF411	INTEGRATED CIRCUIT
U420	I3	CA3081	INTEGRATED CIRCUIT
U421	F2	74C74	INTEGRATED CIRCUIT
U501	E8	LF347	INTEGRATED CIRCUIT
U502	D8	AD7524	INTEGRATED CIRCUIT
U503	H8	74HC374	INTEGRATED CIRCUIT
U504	D8	D6528	INTEGRATED CIRCUIT
U505	F8	AD7542	INTEGRATED CIRCUIT
U506	G8	AD7524	INTEGRATED CIRCUIT
U507	G7	D6528	INTEGRATED CIRCUIT
U508	D6	LF347	INTEGRATED CIRCUIT
U509	D6	D6211	INTEGRATED CIRCUIT
U510	F6	D6211	INTEGRATED CIRCUIT
U511	F7	LF347	INTEGRATED CIRCUIT
U512	G6	LF347	INTEGRATED CIRCUIT
U513	G5	LF347	INTEGRATED CIRCUIT
U514	E5	LM311	INTEGRATED CIRCUIT
U515	D5	LF347	INTEGRATED CIRCUIT
U516	G6	D6211	INTEGRATED CIRCUIT
U517	E7	LH0071	INTEGRATED CIRCUIT
U701	N10	Z80A-CPU	INTEGRATED CIRCUIT
U702	M9	27128-250	INTEGRATED CIRCUIT
U703	M9	HM6116LP	INTEGRATED CIRCUIT
U704	N9	UPD8253	INTEGRATED CIRCUIT
U705	K10	74HC138	INTEGRATED CIRCUIT
U706	K10	74HC138	INTEGRATED CIRCUIT
U707	K9	74HC138	INTEGRATED CIRCUIT
U708	O8	74HC157	INTEGRATED CIRCUIT
U709	O9	74HC74	INTEGRATED CIRCUIT
U710	M12	74HC32	INTEGRATED CIRCUIT
U711	O12	74HCU04	INTEGRATED CIRCUIT
U712	N12	74HC4040	INTEGRATED CIRCUIT
U713	N12	74HC74	INTEGRATED CIRCUIT
U714	K8	74HC175	INTEGRATED CIRCUIT
U715	O12	74HC175	INTEGRATED CIRCUIT
U716	J8	74HC244	INTEGRATED CIRCUIT
U717	I8	74HC374	INTEGRATED CIRCUIT
U718	I7	74HC14	INTEGRATED CIRCUIT
U719	O13	74HC374	INTEGRATED CIRCUIT
U720	O14	74HC374	INTEGRATED CIRCUIT
U721	I8	74HC374	INTEGRATED CIRCUIT
U722	L12	74HC32	INTEGRATED CIRCUIT
U801	G9	UPD8251A	INTEGRATED CIRCUIT
U802	I9	MC6B488	INTEGRATED CIRCUIT
U803	C14	74HC244	INTEGRATED CIRCUIT
U804	D14	74HC244	INTEGRATED CIRCUIT
U805	M12	74HC74	INTEGRATED CIRCUIT
U806	G15	MC1488	INTEGRATED CIRCUIT
U807	G15	MC1489	INTEGRATED CIRCUIT
U808	H14	DS75160	INTEGRATED CIRCUIT
U809	G14	MC78L12	INTEGRATED CIRCUIT
U810	G14	MC79L12	INTEGRATED CIRCUIT
U811	H14	DS75161	INTEGRATED CIRCUIT
U901	E12	LM317	INTEGRATED CIRCUIT
U902	E14	LM337	INTEGRATED CIRCUIT
U903	A14	MC7815	INTEGRATED CIRCUIT
U904	O7	MC7815	INTEGRATED CIRCUIT
U905	D10	MC7815	INTEGRATED CIRCUIT
U906	A15	MC7915	INTEGRATED CIRCUIT
U907	O7	MC7915	INTEGRATED CIRCUIT
U908	D10	MC7915	INTEGRATED CIRCUIT
U909	F14	MC7805K	INTEGRATED CIRCUIT
U910	B14	MC78L05	INTEGRATED CIRCUIT
U911	C8	LM317L	INTEGRATED CIRCUIT
U912	C9	LM337L	INTEGRATED CIRCUIT

Quadrature Detector Board Parts List

REF NO	LOC	VALUE	DESCRIPTION
C1001		470P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1002		10U	CE
C1004		1.0U	CAPACITOR, STACKED METAL FILM
C1005		.001U	CAPACITOR, STACKED METAL FILM
C1006		.33U	CAPACITOR, STACKED METAL FILM
C1007		.001U	CAPACITOR, STACKED METAL FILM
C1008		10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1009		10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1010		47U	CEEEA
C1011		47U	CEEEA
C1012		47U	CEEEA
C1013		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C1014		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C1015		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C1016		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C1017		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C1018		22P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1101		1.0U	CAPACITOR, STACKED METAL FILM
C1102		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1103		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1104		1.0U	CAPACITOR, STACKED METAL FILM
C1105		1.0U	CAPACITOR, STACKED METAL FILM
C1106		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1107		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1108		10P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1109		.1U	CAPACITOR, STACKED METAL FILM
C1110		.1U	CAPACITOR, STACKED METAL FILM
C1111		.1U	CAPACITOR, STACKED METAL FILM
C1112		.1U	CAPACITOR, STACKED METAL FILM
C1113		.001U	CAPACITOR, STACKED METAL FILM
C1114		.033U	CAPACITOR, STACKED METAL FILM
C1115		10U	CAPACITOR, MYLAR/POLY, 50V, 5%, RADIAL
C1116		.1U	CAPACITOR, STACKED METAL FILM
C1117		1.0U	CAPACITOR, STACKED METAL FILM
C1120		.1U	CAPACITOR, STACKED METAL FILM
C1121		33P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1122		33P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1123		.047U	CAPACITOR, STACKED METAL FILM
C1124		.047U	CAPACITOR, STACKED METAL FILM
C1125		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1126		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1201		330P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C1202		.0047U	CAPACITOR, POLYSTYRENE, 50V, 5%, RADIAL
C1203		.001U	CAPACITOR, STACKED METAL FILM
C1204		.001U	CAPACITOR, STACKED METAL FILM
C1205		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1206		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1207		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C1208		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
D1001		1N4148	DIODE
D1002		1N4148	DIODE
D1103		1N4148	DIODE
D1104		1N4148	DIODE
PCB1	OFF	SR522	PRINTED CIRCUIT BOARD
P1101		10K	PBS
P1102		10K	PBS
P1103		10K	PBS
P1104		10K	PBS
P1201		10K	PBS
P1202		10K	PBS
Q1201		2N5210	TRANSISTOR, TO-92 PACKAGE
R1001		2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1002		1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1003		1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1004		1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1005		300K	RESISTOR, CARBON FILM, 1/4W, 5%
R1006		6.2K	RESISTOR, CARBON FILM, 1/4W, 5%
R1007		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R1008		300K	RESISTOR, CARBON FILM, 1/4W, 5%
R1009		2.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R1010		330K	RESISTOR, CARBON FILM, 1/4W, 5%
R1011		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1012		10.0K	RESISTOR, METAL FILM, 1/8W, 1%
R1013		75.0K	RESISTOR, METAL FILM, 1/8W, 1%
R1014		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1015		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R1016		4.53K	RESISTOR, METAL FILM, 1/8W, 1%
R1017		2.26K	RESISTOR, METAL FILM, 1/8W, 1%
R1018		2.80K	RESISTOR, METAL FILM, 1/8W, 1%
R1019		5.1K	RESISTOR, CARBON FILM, 1/4W, 5%
R1020		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1021		32.4K	RESISTOR, METAL FILM, 1/8W, 1%
R1022		1.10K	RESISTOR, METAL FILM, 1/8W, 1%
R1023		130K	RESISTOR, METAL FILM, 1/8W, 1%
R1024		16.2K	RESISTOR, METAL FILM, 1/8W, 1%
R1025		1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R1026		1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R1027		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R1028		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1029		2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1030		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1031		10	RESISTOR, CARBON FILM, 1/4W, 5%
R1032		10	RESISTOR, CARBON FILM, 1/4W, 5%
R1033		10	RESISTOR, CARBON FILM, 1/4W, 5%
R1034		100M	RESISTOR, CARBON FILM, 1/4W, 5%
R1035		100M	RESISTOR, CARBON FILM, 1/4W, 5%
R1036		4.53K	RESISTOR, METAL FILM, 1/8W, 1%
R1037		2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1101		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1102		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1103		5.1M	RESISTOR, CARBON FILM, 1/4W, 5%
R1104		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1105		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1106		499	RESISTOR, METAL FILM, 1/8W, 1%
R1107		1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R1108		1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R1109		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R1110		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1111		499	RESISTOR, METAL FILM, 1/8W, 1%
R1112		1.000K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1113		75.0K	RESISTOR, METAL FILM, 1/8W, 1%
R1114		47	RESISTOR, CARBON FILM, 1/4W, 5%
R1115		100K	RESISTOR, METAL FILM, 1/8W, 1%
R1116		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1117		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R1118		1.10K	RESISTOR, METAL FILM, 1/8W, 1%
R1119		30.1K	RESISTOR, METAL FILM, 1/8W, 1%
R1120		348K	RESISTOR, METAL FILM, 1/8W, 1%
R1121		150K	RESISTOR, METAL FILM, 1/8W, 1%
R1122		37.4K	RESISTOR, METAL FILM, 1/8W, 1%
R1123		9.76K	RESISTOR, METAL FILM, 1/8W, 1%
R1124		2.49K	RESISTOR, METAL FILM, 1/8W, 1%
R1125		1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1126		2.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1127		1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R1128		1.00M	RESISTOR, METAL FILM, 1/8W, 1%
R1129		110K	RESISTOR, METAL FILM, 1/8W, 1%
R1130		10.2K	RESISTOR, METAL FILM, 1/8W, 1%
R1132		1.0K	RESISTOR, CARBON FILM, 1/4W, 5%
R1201		10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1202		20.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1203		10.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1204		20.00K	RESISTOR, METAL FILM, 1/8W, 0.1%
R1205		9.09K	RESISTOR, METAL FILM, 1/8W, 1%
R1206		1.00K	RESISTOR, METAL FILM, 1/8W, 1%
R1207		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1208		100K	RESISTOR, CARBON FILM, 1/4W, 5%
R1209		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R1210		220	RESISTOR, CARBON FILM, 1/4W, 5%

REF NO	LOC	VALUE	DESCRIPTION
R1211		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R1212		220	RESISTOR, CARBON FILM, 1/4W, 5%
U1001		LM311	INTEGRATED CIRCUIT
U1002		CD4046	INTEGRATED CIRCUIT
U1003		DG211	INTEGRATED CIRCUIT
U1004		LM311	INTEGRATED CIRCUIT
U1005		LM13600	INTEGRATED CIRCUIT
U1006		CA3140E	INTEGRATED CIRCUIT
U1007		DG211	INTEGRATED CIRCUIT
U1008		CA3140E	INTEGRATED CIRCUIT
U1009		LM13600	INTEGRATED CIRCUIT
U1010		LM13600	INTEGRATED CIRCUIT
U1011		DG211	INTEGRATED CIRCUIT
U1012		LM311	INTEGRATED CIRCUIT
U1013		CD4018	INTEGRATED CIRCUIT
U1014		LF412	INTEGRATED CIRCUIT
U1101		DG211	INTEGRATED CIRCUIT
U1102		LF412	INTEGRATED CIRCUIT
U1103		LF411	INTEGRATED CIRCUIT
U1104		LT1007	INTEGRATED CIRCUIT
U1105		CD4066	INTEGRATED CIRCUIT
U1106		AD534	INTEGRATED CIRCUIT
U1107		LF411	INTEGRATED CIRCUIT
U1108		LT1007	INTEGRATED CIRCUIT
U1109		LF411	INTEGRATED CIRCUIT
U1110		ICL7650	INTEGRATED CIRCUIT
U1111		RELAY	INTEGRATED CIRCUIT
U1112		RELAY	INTEGRATED CIRCUIT
U1113		RELAY	INTEGRATED CIRCUIT
U1114		RELAY	INTEGRATED CIRCUIT
U1115		RELAY	INTEGRATED CIRCUIT
U1116		ICL7650	INTEGRATED CIRCUIT
U1117		RELAY	INTEGRATED CIRCUIT
U1118		DG211	INTEGRATED CIRCUIT
U1119		LF411	INTEGRATED CIRCUIT
U1120		LF353	INTEGRATED CIRCUIT
U1121		74C74	INTEGRATED CIRCUIT
U1201		AD7524	INTEGRATED CIRCUIT
U1202		LF347	INTEGRATED CIRCUIT
U1203		DG211	INTEGRATED CIRCUIT
U1204		LF411	INTEGRATED CIRCUIT
U1205		LF411	INTEGRATED CIRCUIT

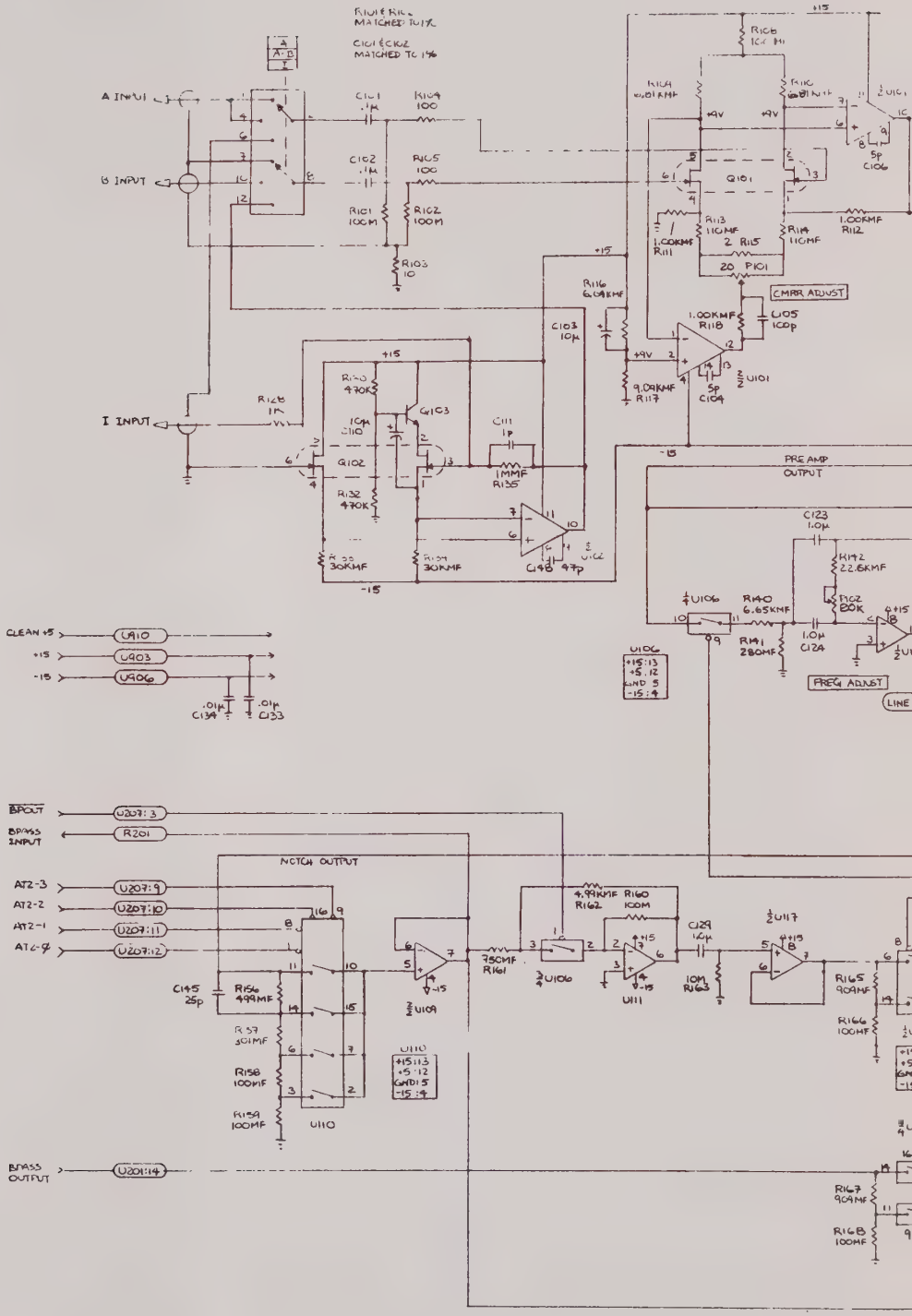
Front Panel Part List

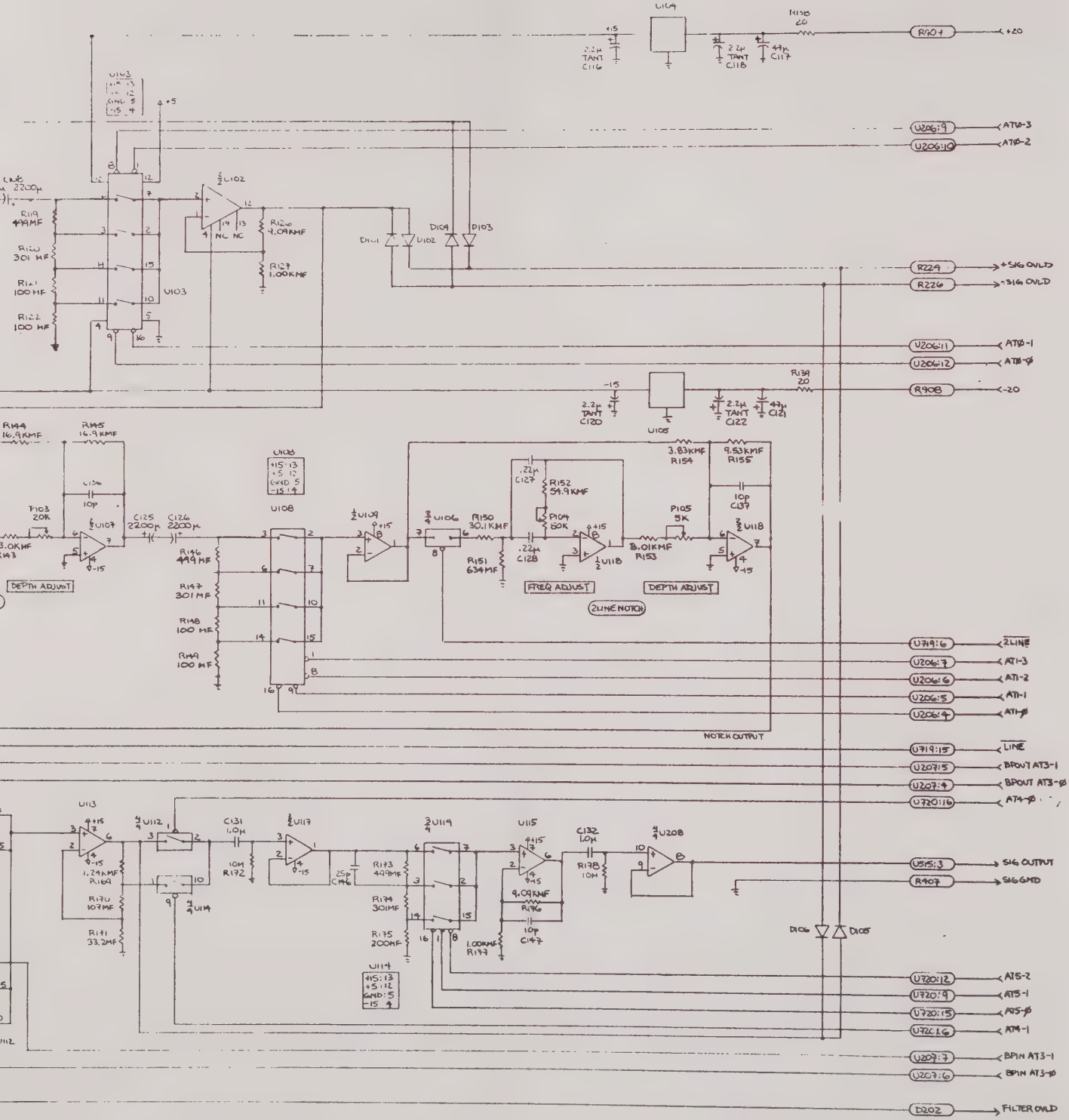
REF NO	LOC	VALUE	DESCRIPTION
C601		.01U	CAPACITOR, STACKED METAL FILM
C602		68P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C603		.01U	CAPACITOR, STACKED METAL FILM
C604		68P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C605		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C606		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C607		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C608		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C609		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C610		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
DS601		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
D601		1N4148	DIODE
DS602		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
D602		1N4148	DIODE
DS603		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
D603		1N4148	DIODE
DS604		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
D604		1N4148	DIODE
DS605		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS606		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS607		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS608		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS609		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS610		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS611		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS612		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS613		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS614		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS615		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS616		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS617		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS618		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS619		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS620		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS621		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS622		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS623		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS624		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS625		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS626		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS627		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS628		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS629		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS630		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS631		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS632		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS633		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS634		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS635		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS636		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS637		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS638		HLMP-0301	DIODE, RED LIGHT EMITTING, RECTANGULAR
DS639		HLMP-0301	DIODE, RED LIGHT EMITTING, RECTANGULAR
DS640		HLMP-0301	DIODE, RED LIGHT EMITTING, RECTANGULAR
DS641		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS642		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS643		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS644		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS645		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS646		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS647		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS648		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS649		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS650		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS651		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS652		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS653		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS654		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS655		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS656		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS657		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS658		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS659		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS660		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS661		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS662		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS663		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS664		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS665		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS666		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS667		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS668		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS669		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS670		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
DS671		HLMP-0504	DIODE, GREEN LIGHT EMITTING, RECTANGULAR
LCD1		FE0206	LIQUID CRYSTAL DISPLAY
LCD2		FE0206	LIQUID CRYSTAL DISPLAY
LCD3		FE0206	LIQUID CRYSTAL DISPLAY
M1		-10/0/10S	ANALOG METER
M2		-10/0/10S	ANALOG METER
PCB1	OFF	SR521	PRINTED CIRCUIT BOARD
PB601		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB602		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB603		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB604		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB605		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB606		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB607		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB608		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB609		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB610		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB611		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB612		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB613		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB614		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB615		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB616		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB617		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB618		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB619		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB620		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB621		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB622		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB623		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB624		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB625		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB626		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB627		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB628		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB629		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB630		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
PB631		D6-01-01	SWITCH, MOMENTARY PUSH BUTTON, NORM OPEN
RN601		9X22K	RESISTOR NETWORK, SIP, 1/4W, 2%
R601		10K	RESISTOR, CARBON FILM, 1/4W, 5%
RN602		9X150	RESISTOR NETWORK, SIP, 1/4W, 2%
R602		10K	RESISTOR, CARBON FILM, 1/4W, 5%
RN603		9X150	RESISTOR NETWORK, SIP, 1/4W, 2%
RN604		7X150	RESISTOR NETWORK, SIP, 1/4W, 2%
SW602		DPDT	SWARK
U601		ICM7211AM	INTEGRATED CIRCUIT
U602		ICM7211AM	INTEGRATED CIRCUIT
U603		ICM7211AM	INTEGRATED CIRCUIT
U604		CD4030	INTEGRATED CIRCUIT
U605		CD4030	INTEGRATED CIRCUIT
U606		CD4030	INTEGRATED CIRCUIT
U607		74HC374	INTEGRATED CIRCUIT
U608		74HC175	INTEGRATED CIRCUIT
U609		74HC244	INTEGRATED CIRCUIT
U610		74LS164	INTEGRATED CIRCUIT
U611		74LS164	INTEGRATED CIRCUIT

REF NO	LOC	VALUE	DESCRIPTION
U612		74LS164	INTEGRATED CIRCUIT
U613		74LS164	INTEGRATED CIRCUIT
U614		74LS164	INTEGRATED CIRCUIT
U615		74LS164	INTEGRATED CIRCUIT
U616		74LS164	INTEGRATED CIRCUIT
U617		74LS164	INTEGRATED CIRCUIT
U618		74LS164	INTEGRATED CIRCUIT

Internal Oscillator Parts List

REF NO	LOC	VALUE	DESCRIPTION
C1		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C2		.1U	CAPACITOR, CERAMIC DISC, 50V, 20%, Z5U
C3		4.7U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C4		4.7U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C5		390P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C6		.047U	CAPACITOR, STACKED METAL FILM
C7		390P	CAPACITOR, CERAMIC DISK, 50V, 10%, SL
C8		100U	CEEEA
C9		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
C10		100U	CEEEA
C11		2.2U	CAPACITOR, TANTALUM, 35V, 20%, RADIAL
PCB1	OFF	SR501	PRINTED CIRCUIT BOARD
P1		10K	PBS
P2		100K	PCB MOUNT TRIM POT, INLINE LEADS, .1"
P3		10K	PBS
R1		4.7K	RESISTOR, CARBON FILM, 1/4W, 5%
R2		47K	RESISTOR, CARBON FILM, 1/4W, 5%
R3		698	RESISTOR, METAL FILM, 1/8W, 1%
R4		41.2K	RESISTOR, METAL FILM, 1/8W, 1%
R5		4.22K	RESISTOR, METAL FILM, 1/8W, 1%
R6		42.2K	RESISTOR, METAL FILM, 1/8W, 1%
R7		4.22K	RESISTOR, METAL FILM, 1/8W, 1%
R8		698	RESISTOR, METAL FILM, 1/8W, 1%
R9		39K	RESISTOR, CARBON FILM, 1/4W, 5%
R10		4.22K	RESISTOR, METAL FILM, 1/8W, 1%
R11		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R12		15K	RESISTOR, CARBON FILM, 1/4W, 5%
R13		30K	RESISTOR, CARBON FILM, 1/4W, 5%
R14		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R15		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R16		4.7K	RESISTOR, CARBON FILM, 1/4W, 5%
R17		82K	RESISTOR, CARBON FILM, 1/4W, 5%
R18		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R19		10K	RESISTOR, CARBON FILM, 1/4W, 5%
R20		4.99K	RESISTOR, METAL FILM, 1/8W, 1%
R21		4.99K	RESISTOR, METAL FILM, 1/8W, 1%
R22		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R23		1.0M	RESISTOR, CARBON FILM, 1/4W, 5%
R24		100	RESISTOR, CARBON FILM, 1/4W, 5%
R25		100	RESISTOR, CARBON FILM, 1/4W, 5%
SW1		DPDT	SWBRT
SW2		DPDT	SWBRT
U1		LF347	INTEGRATED CIRCUIT
U2		8038	INTEGRATED CIRCUIT
U3		MC78L15	INTEGRATED CIRCUIT
U4		MC79L15	INTEGRATED CIRCUIT

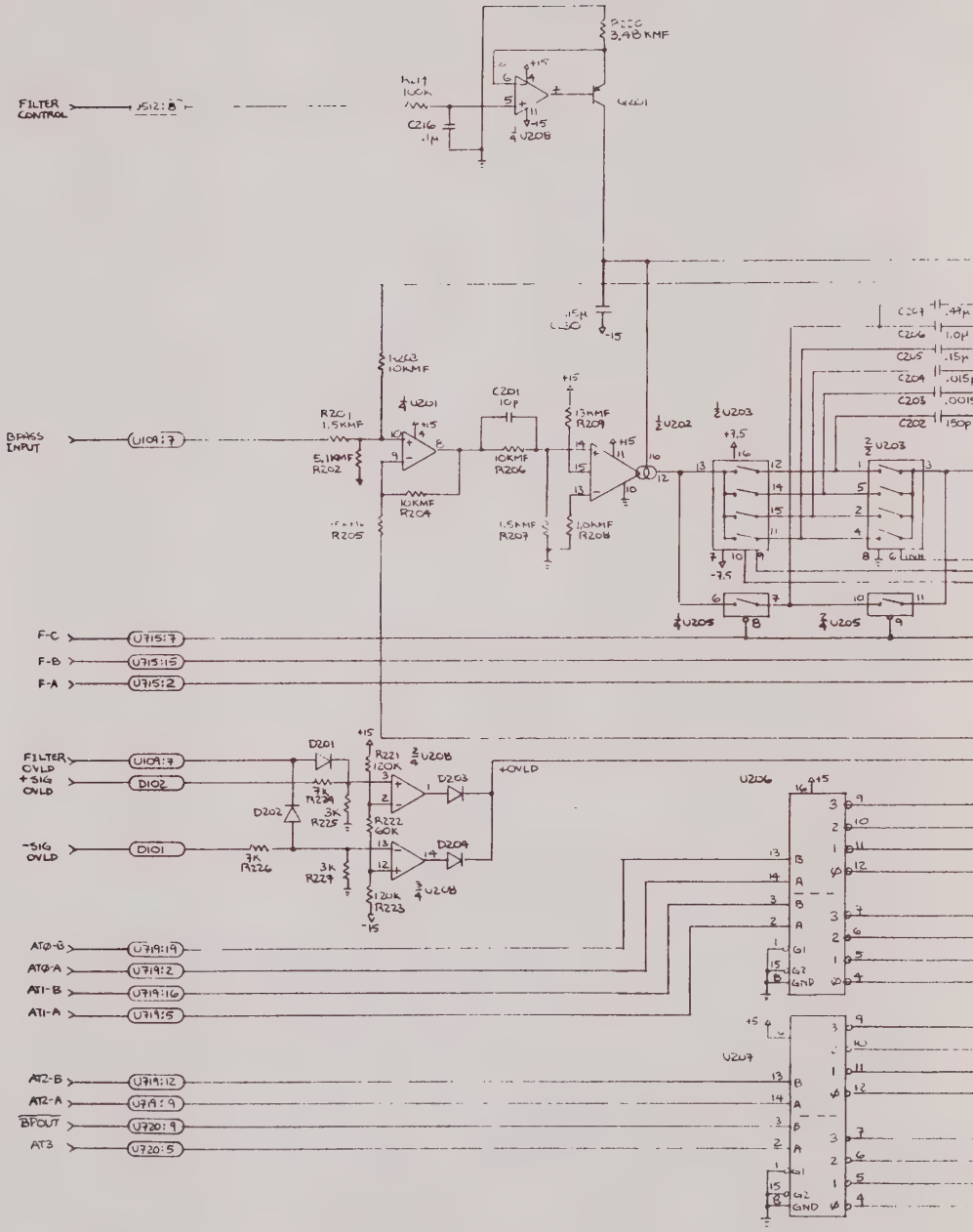

A INPUT
B INPUT
I INPUT
CMRR ADJUST
PREAMP OUTPUT
FREQ ADJUST
LINE
CLEAN +5
+15
-15
BPOUT
BPASS INPUT
NOTCH OUTPUT
AT2-3
AT2-2
AT2-1
AT2-0
BPASS OUTPUT

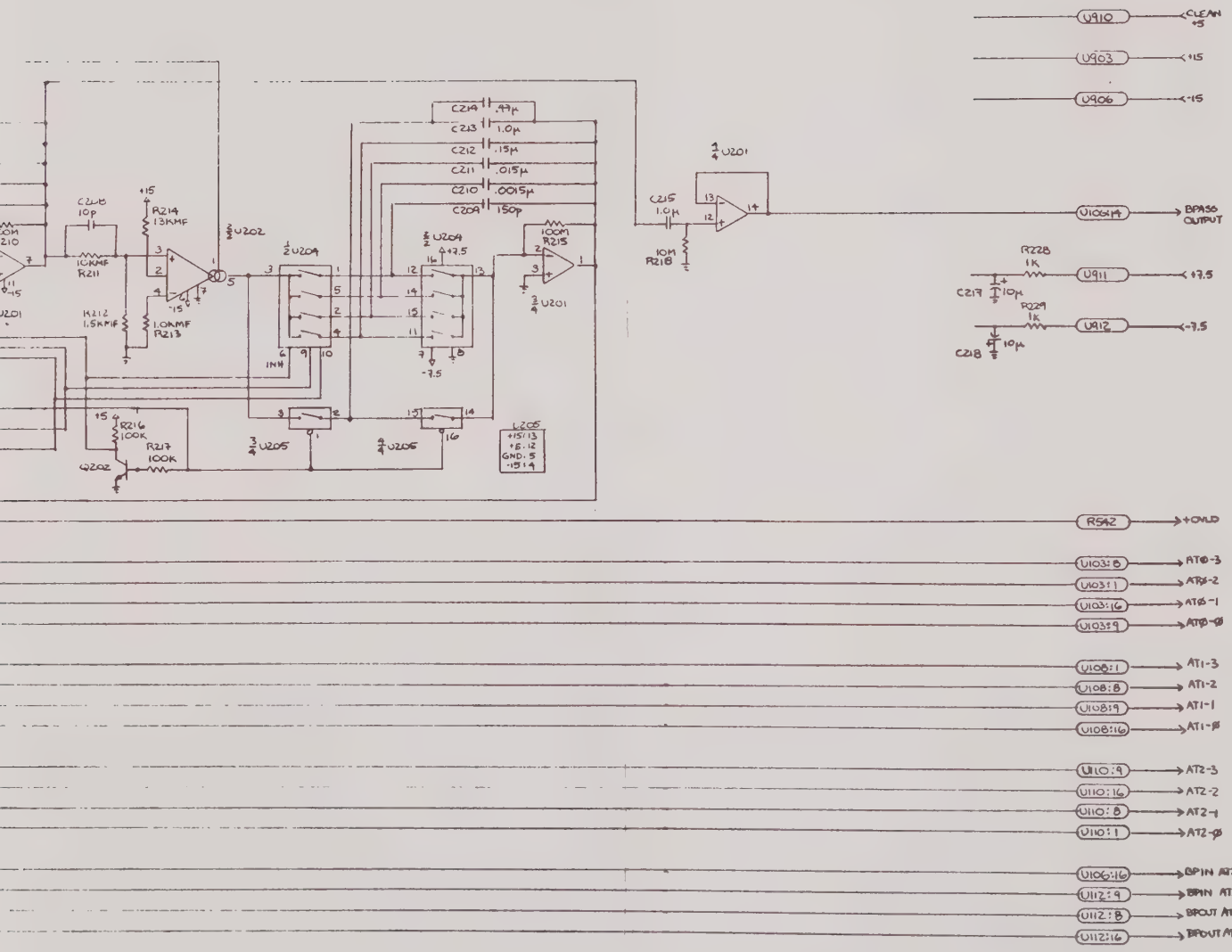


U104	XR1458	U111	LF354
U102	XR4558	U112	[illegible]
U103	DG211	U113	LF354
U107	74LS15	U114	DG211
U106	DG211	U115	LF354
U105	XR5532	U116	REMOVED
U108	DG211	U117	LF353
U109	LF353 (XR5532)	U118	XR5532
U110	DG211		

STANFORD RESEARCH SYSTEMS	SIGNAL AMPLIFIER			
DRAWN 9-26-84	SIZE	FSCM NO.	DWG. NO. SR500 - 1	REV. B
ISSUED	SCALE	JCW	SHEET 1	

BISHOP GRAPHICS, INC. REORDER NO. 1860 UPDATED 2-22-85

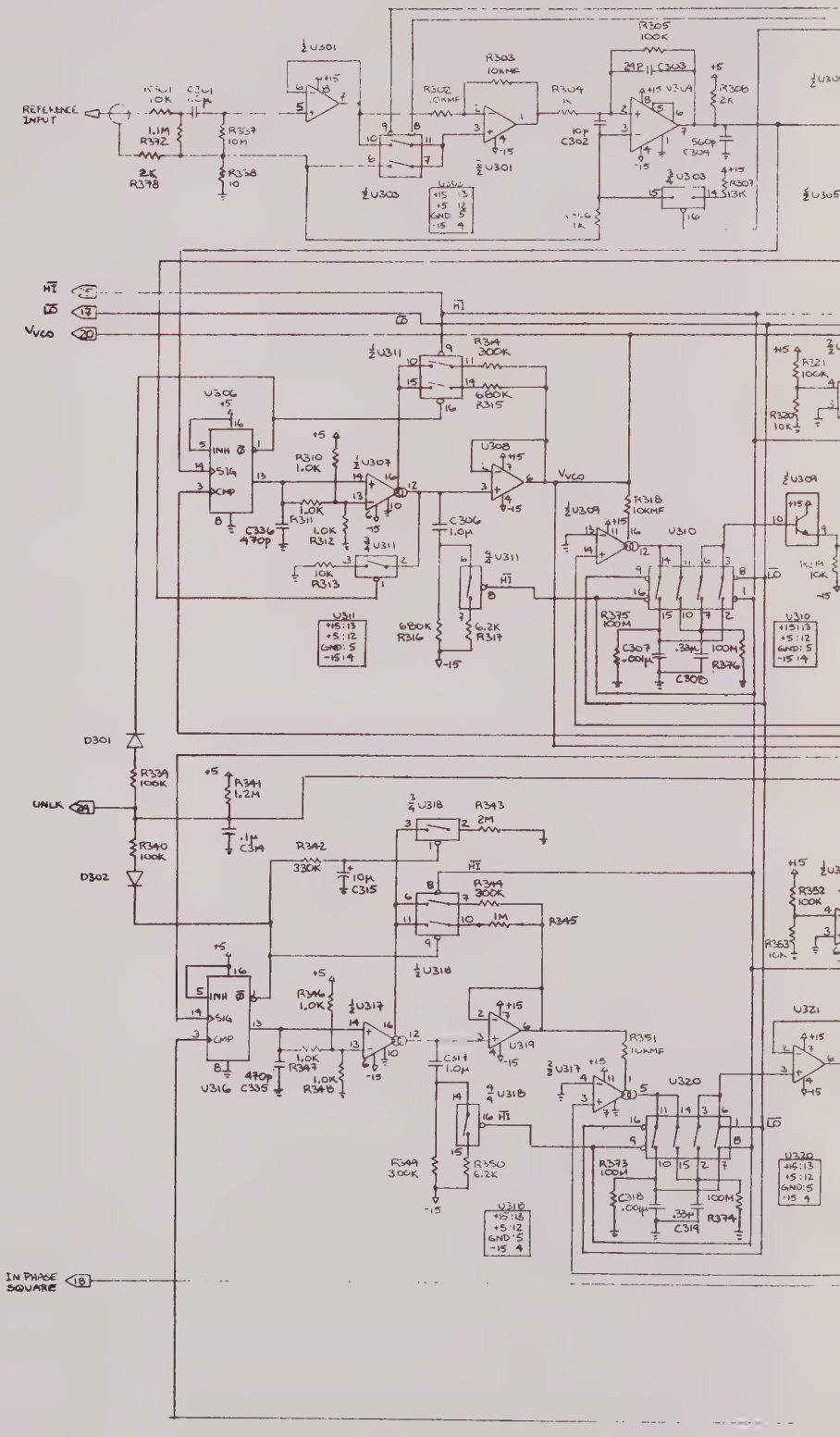

FILTER CONTROL
J512:8
C216 .1M
R219 100K
R220 3.98 KMF
Q201
¼ U208
+15
-15
.15M C210
R201 1.5KMF
R202 5.11KMF
R203 10KMF
R204 10KMF
R205
C201 10P
R206 10KMF
R207 1.5KMF
R208 1.0KMF
R209 13KMF
¼ U201
½ U202
½ U203
+7.5
-7.5
C207 .47µ
C206 1.0µ
C205 .15µ
C204 .015µ
C203 .0015µ
C202 150P
BYPASS INPUT
U109:7
F-C
F-B
F-A
U715:7
U715:15
U715:2
FILTER OVLD
+SIG OVLD
-SIG OVLD
D102
D101
D201
D202
D203
D204
R221 120K
R222 60K
R223 120K
R224 3K
R225 3K
R226 3K
R227 3K
¼ U208
¾ U208
+OVLD
AT0-B
AT0-A
AT1-B
AT1-A
U719:19
U719:2
U719:16
U719:5
AT2-B
AT2-A
BPOUT
AT3
U719:12
U719:9
U720:9
U720:5
U206
U207
GND

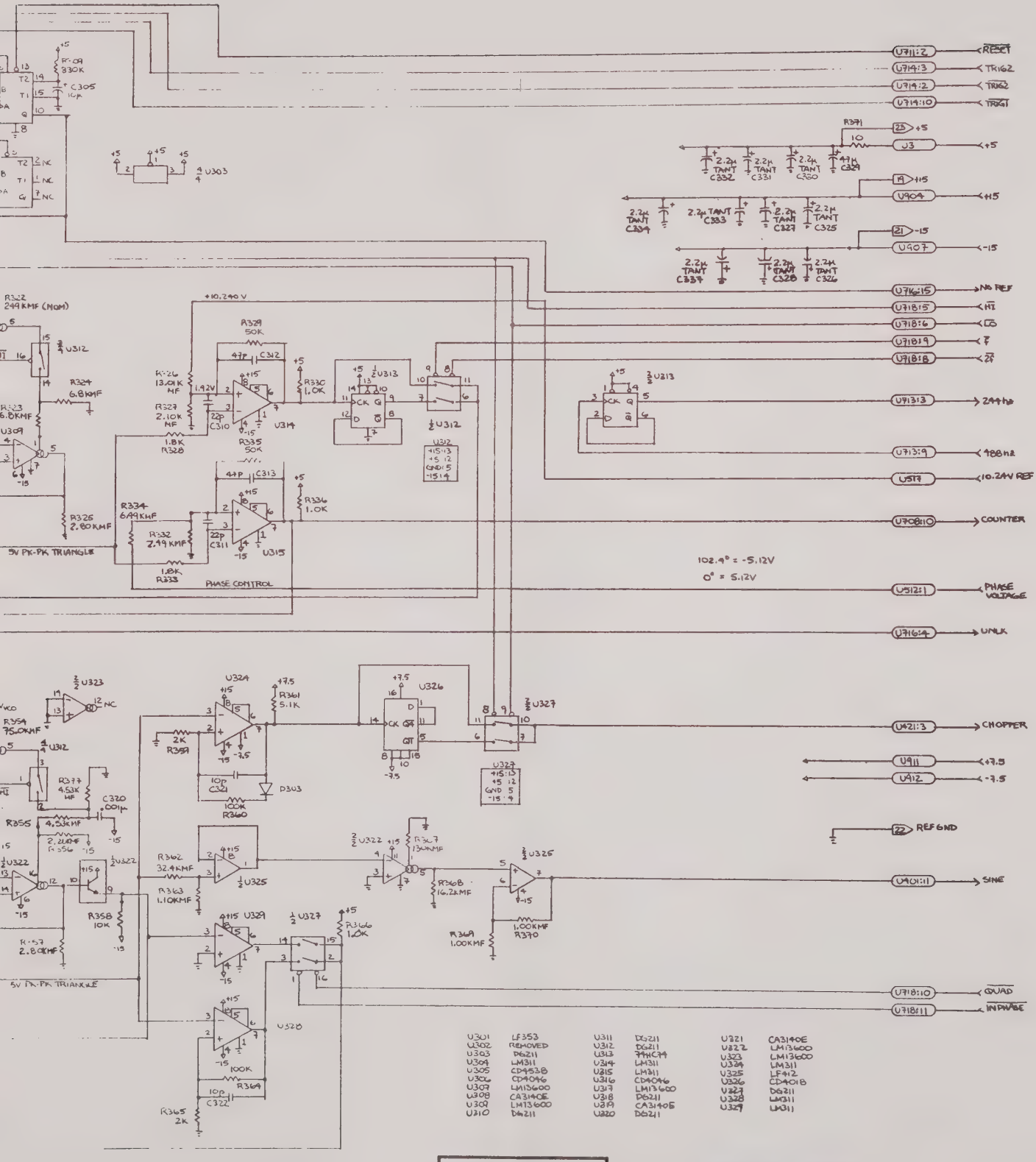


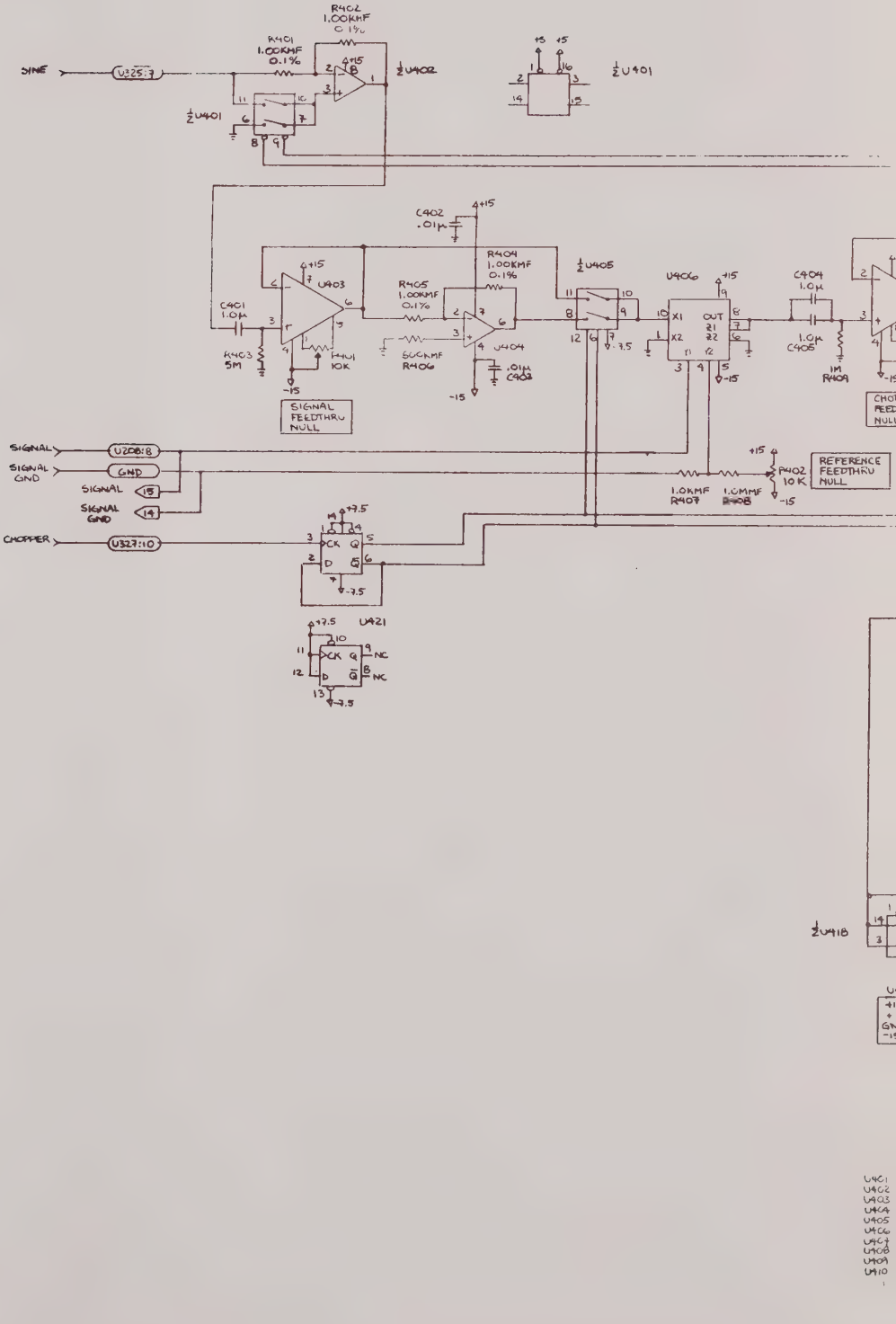
U201	LF347
U202	LM360
U203	CD4052
U204	CD4052
U205	DG211
U206	74HC139
U209	74HC139
U208	LF347

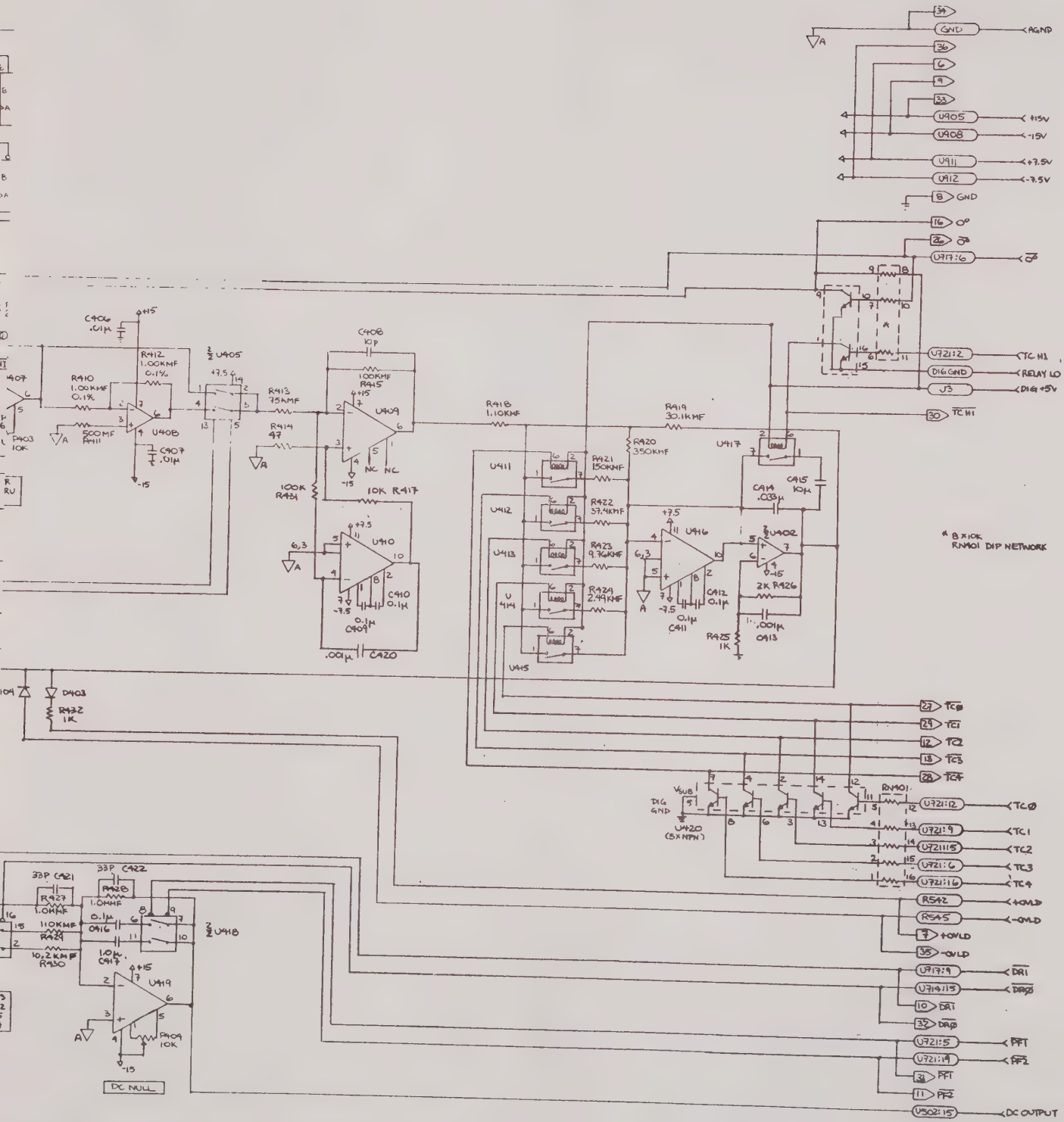
STANFORD RESEARCH SYSTEMS	BANDPASS FILTER			
DRAWN 9-25-84	SIZE	FSCM NO.	DWG. NO. SR500-2	REV. B
ISSUED	SCALE	JCW	SHEET 2	

BISHOP GRAPHICS, INC. REORDER NO 1860
UPDATED 2-22-85


REFERENCE INPUT
UNLK
IN PHASE SQUARE
VVCO
D301
D302
R339 100K
R340 100K
R341 1.2M
.1M C314
R342 330K
10M C315
R343 2M
R345 1M
R346 1.0K
R347 1.0K
R348 1.0K
C316 470P
C317 1.0M
R349 300K
R350 6.2K
R351 10KMF
R352 100K
R363 10K
U316
U317
U318
U319
U320
U321
R305 100K
R306 2K
R307 13K
R308 1K
R309 1K
R310 1.0K
R311 1.0K
R312 1.0K
R313 10K
C306 1.0M
C307 .001M
C308 .33M
R375 100M
R376 100M
R318 10KMF
R319 300K
R315 680K
R316 680K
R317 6.2K
R321 100K
R320 10K
C318 .001M
C319 .33M
R373 100M
R374 100M
U306
U307
U308
U309
U310
U311


U711:2 RESET
U719:3 TR162
U719:2 TR62
U719:10 TRIGI
R371
U3 +5
U904 +5
U907 -15
U716:15 NO REF
U718:15 HI
U718:6 CO
U718:9 Z
U718:8 Z
U913:3 244hz
U713:9 488hz
U517 10.24V REF
U708:10 COUNTER
U512:1 PHASE VOLTAGE
U716:4 UNLK
U421:3 CHOPPER
U911 +7.5
U912 -7.5
22 REF GND
U401:1 SINE
U718:10 QUAD
U718:11 INPHASE
+10.240 V
R322 249KMF (NOM)
R329 50K
R326 13.01K MF
R327 2.10K MF
R324 6.8KMF
R325 2.80KMF
R330 1.0K
R335 50K
R336 1.0K
R334 6.49KMF
R332 2.49 KMF
R320 1.8K
R333 1.8K
PHASE CONTROL
5V PK-PK TRIANGLE
102.9° = -5.12V
0° = 5.12V
R361 5.1K
R359 2K
R360 100K
R362 32.4KMF
R363 1.10KMF
R355 4.53KMF
R356 2.21KMF
R358 10K
R357 2.80KMF
R367 130KMF
R368 16.2KMF
R369 1.00KMF
R370 1.00KMF
R366 1.0K
R365 2K
R369 100K
C305 10µ
C332 2.2µ TANT
C331 2.2µ TANT
C330 2.2µ TANT
C329 47µ
C334 2.2µ TANT
C333 2.2µ TANT
C327 2.2µ TANT
C325 2.2µ TANT
C339 2.2µ TANT
C328 2.2µ TANT
C326 2.2µ TANT
C312 47P
C310 22P
C313 47P
C311 22P
C320 .001µ
C321 10P
C322 10P
D303
U303
U312
U313
U314
U315
U323
U324
U325
U326
U327
U329
U320
U322
U309
U307
U308
U301 LF353
U302 REMOVED
U303 D6211
U304 LM311
U305 CD4538
U306 CD4046
U307 LM13600
U308 CA3140E
U309 LM13600
U310 D6211
U311 D6211
U312 D6211
U313 74HC74
U314 LM311
U315 LM311
U316 CD4046
U317 LM13600
U318 D6211
U319 CA3140E
U320 D6211
U321 CA3140E
U322 LM13600
U323 LM13600
U324 LM311
U325 LF412
U326 CD4018
U327 D6211
U328 LM311
U329 LM311
STANFORD RESEARCH SYSTEMS
REFERENCE OSCILLATOR
DRAWN 9-25-84
ISSUED
SIZE
FSCM NO.
DWG. NO. SR500-3
REV. B
SCALE
JCW
SHEET 3
80
BISHOP GRAPHICS, INC. REORDER NO. 1860
UPDATED 2-22-85


R402
1.00KMF
0.1%
R401
1.00KMF
0.1%
SINE
U325:7
+15
½U402
½U401
½U401
+15
½U401
C402
.01μ
+15
R404
1.00KMF
0.1%
½U405
U406
+15
C404
1.0μ
C401
1.0μ
U403
R405
1.00KMF
0.1%
R403
5M
R401
10K
SIGNAL
FEEDTHRU
NULL
-15
50KMF
R406
U404
.01μ
C403
-15
1.0μ
C405
1M
R409
SIGNAL
U208:8
SIGNAL
GND
GND
SIGNAL
15
SIGNAL
GND
14
+15
REFERENCE
FEEDTHRU
NULL
P402
10K
1.0KMF
R407
1.0MMF
R408
-15
CHOPPER
U327:10
+7.5
-7.5
+7.5
U421
-7.5
½U418



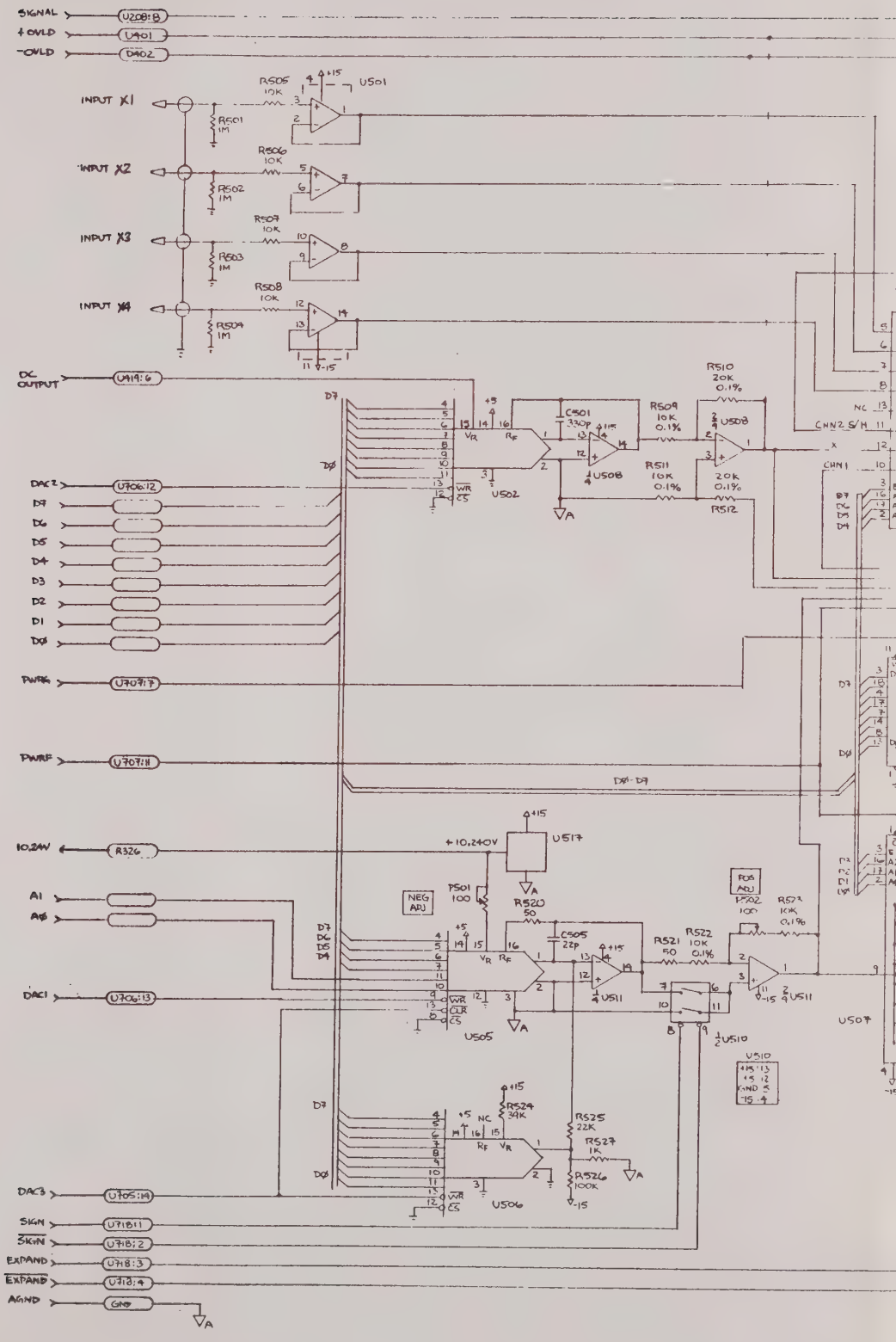
C4211	
R412	
R411	
LT1007	
LM6666	
AD5543	
LF411	
LT1007	
R411	
ICL7650	

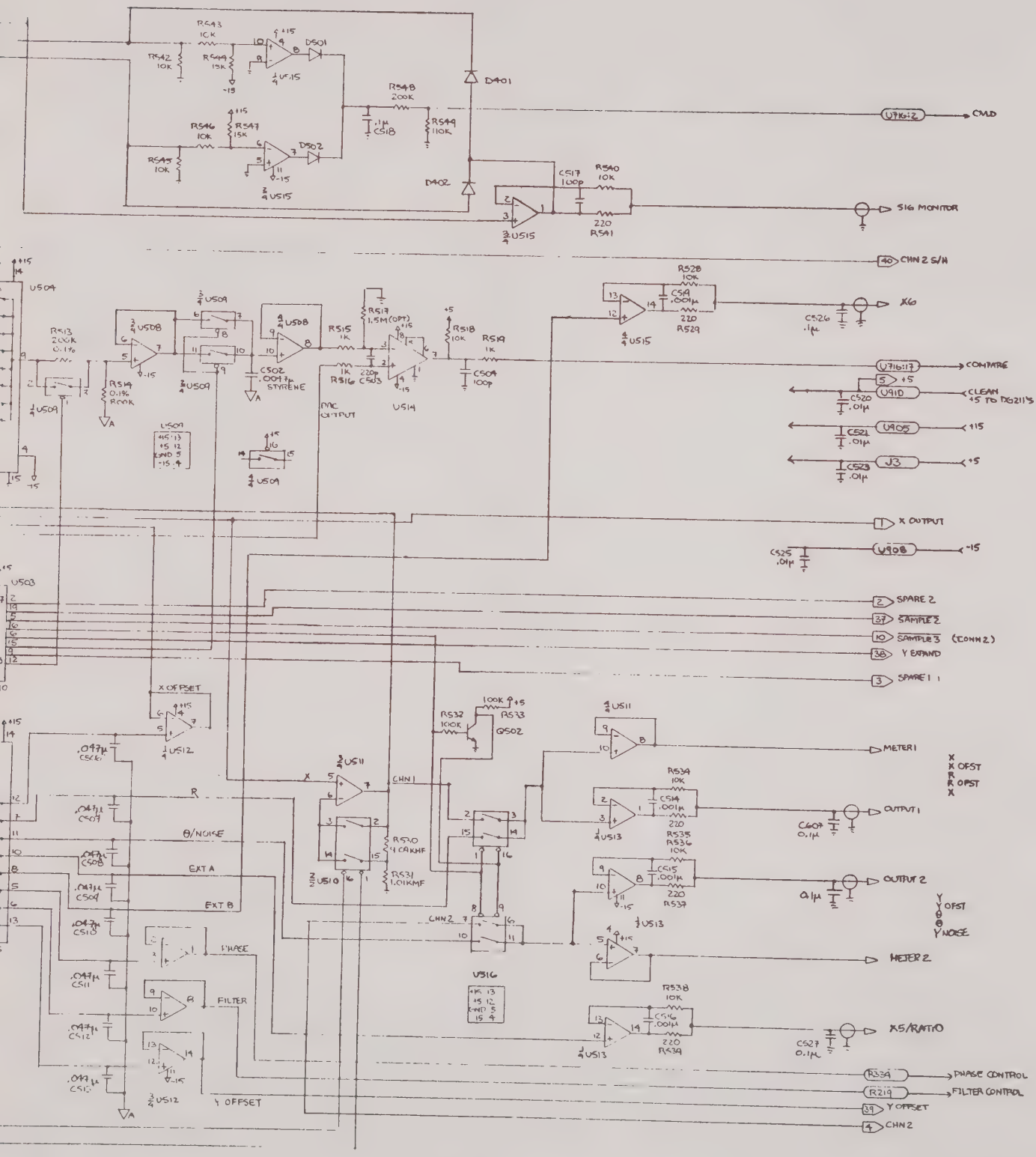
U411	RELAY
U412	RELAY
U413	RELAY
U414	RELAY
U415	RELAY
U416	ICL7650
U417	RELAY
U418	PB211
U419	LF411
U420	CA3081

STANFORD RESEARCH SYSTEMS		DEMODULATOR / LOW PASS AMP	
DRAWN 9-24-84	SIZE	FSCM NO.	DWG. NO. SR500-4 REV. B
ISSUED	SCALE	JCW	SHEET 4

BISHOP GRAPHICS, INC. REORDER NO 1860

UPDATED 2-22-85


SIGNAL
+OVLD
-OVLD
INPUT X1
INPUT X2
INPUT X3
INPUT X4
R501
R502
R503
R504
R505
R506
R507
R508
U501
DC OUTPUT
U502
U505
U506
U507
U508
U509
U510
U511
R509
R510
R511
R512
C501
C505
DAC2
DAC1
DAC3
PWRR
PWRF
10.24V
+10.240V
U517
R520
R521
R522
R524
R525
R526
R527
P501
P502
NEG ADJ
SIGN
EXPAND
AGND
CHN2 S/H
CHN1

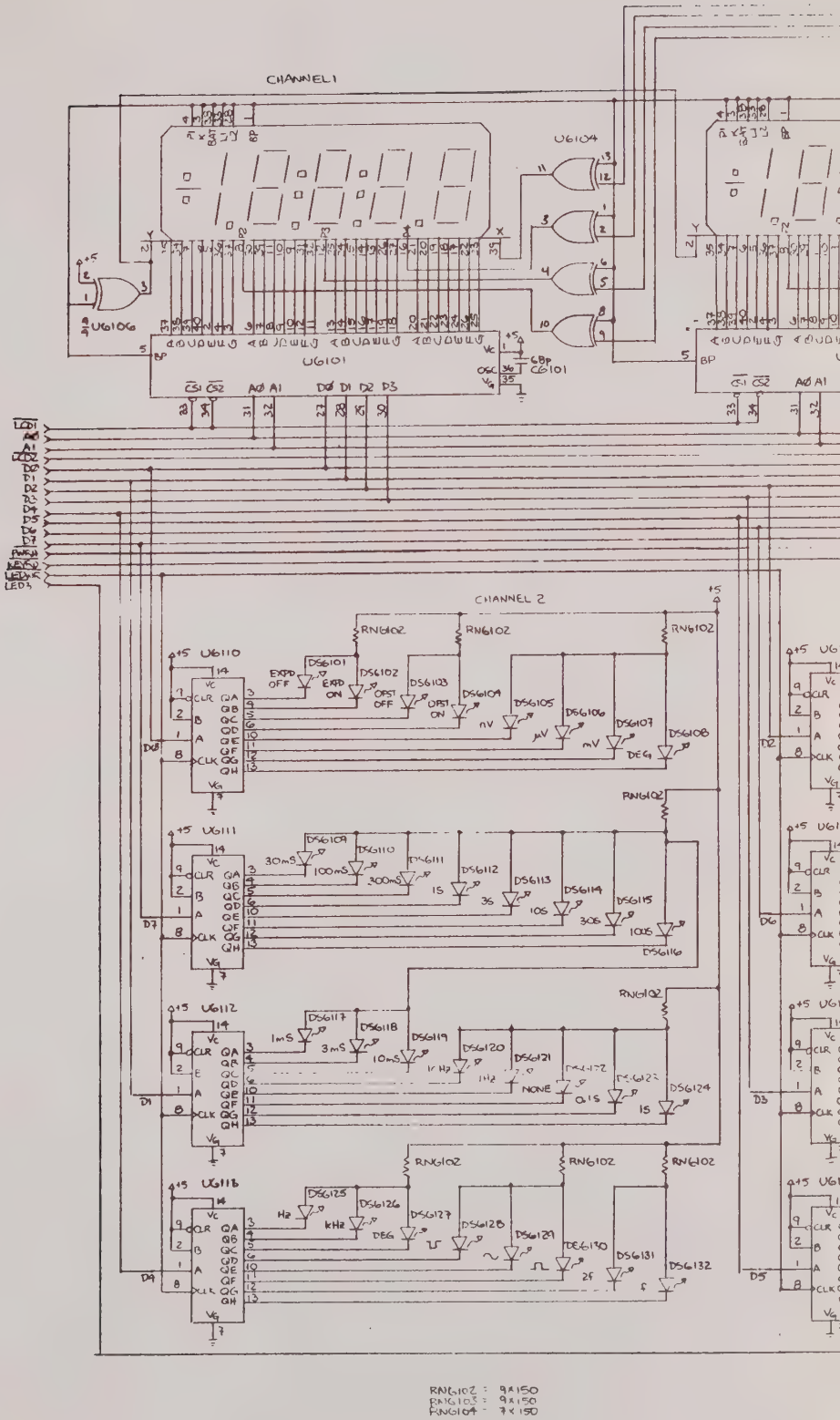


U504	LF347	U511	LF347
U505	AD7524	U512	LF347
U506	74HC374	U513	LF347
U507	LM311	U514	LM311
U508	AD7524	U515	LF347
U509	LF347	U516	DG211 (520 ONLY)
U510	DG211	U517	LH0041

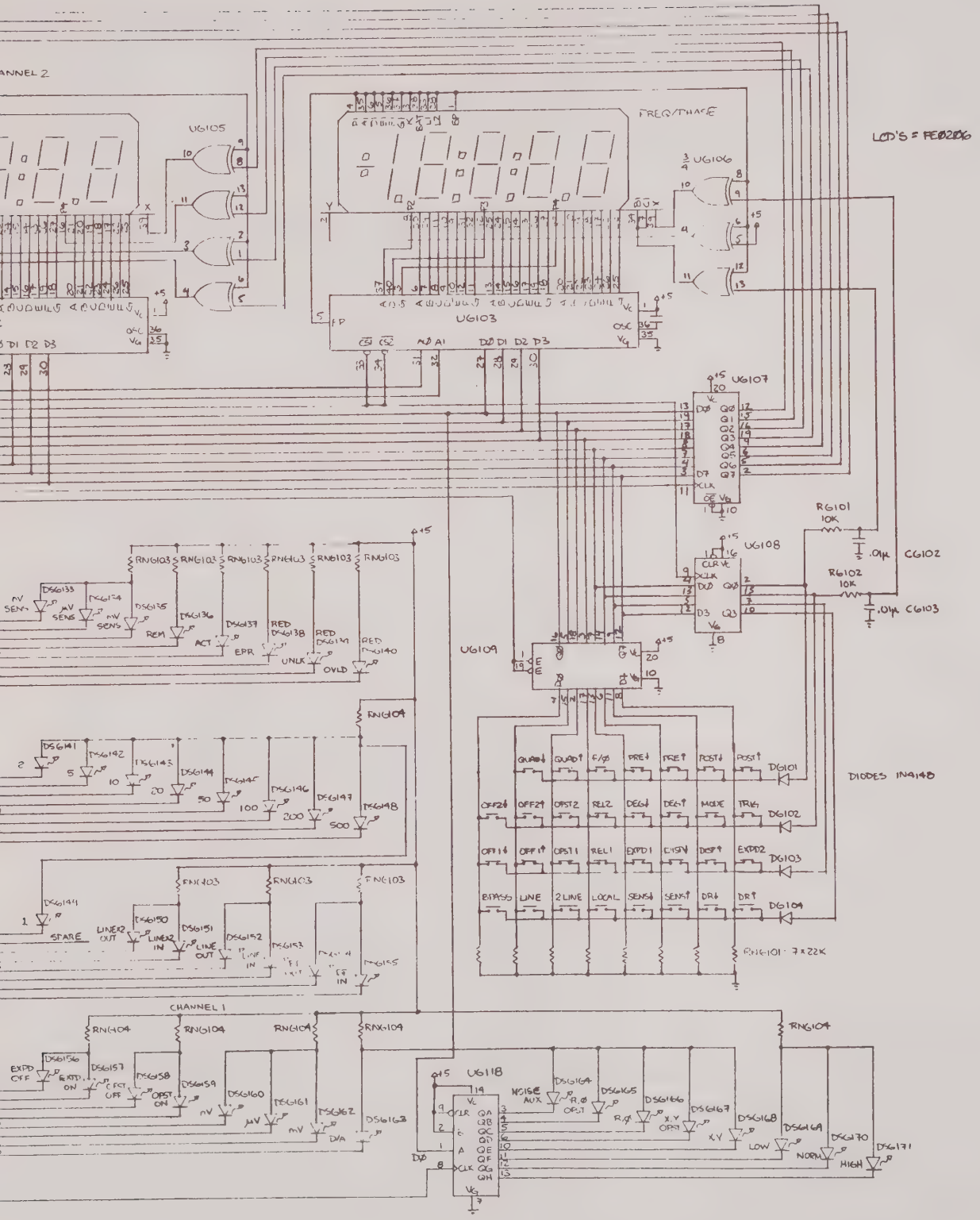
STANFORD RESEARCH SYSTEMS	DC OUTPUTS			
DRAWN 9-26-84	SIZE	FSCM NO.	DWG. NO. SR500-5	REV. B
ISSUED	SCALE	JCW	SHEET 5	

BISHOP GRAPHICS, INC. REORDER NO. 1860

UPDATED 2-22-85



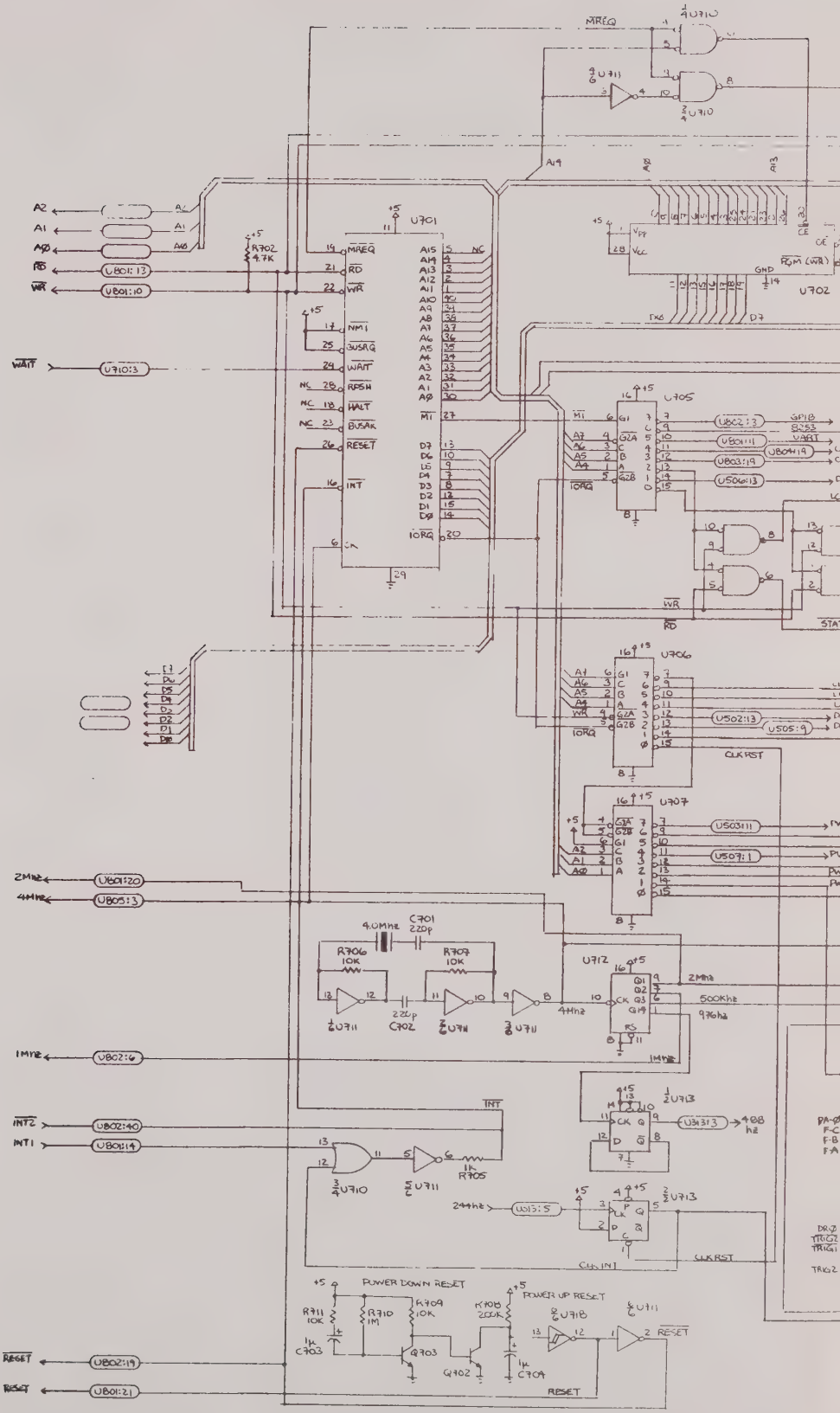
RN6102 : 9x150
RN6103 : 9x150
RN6104 : 7x150

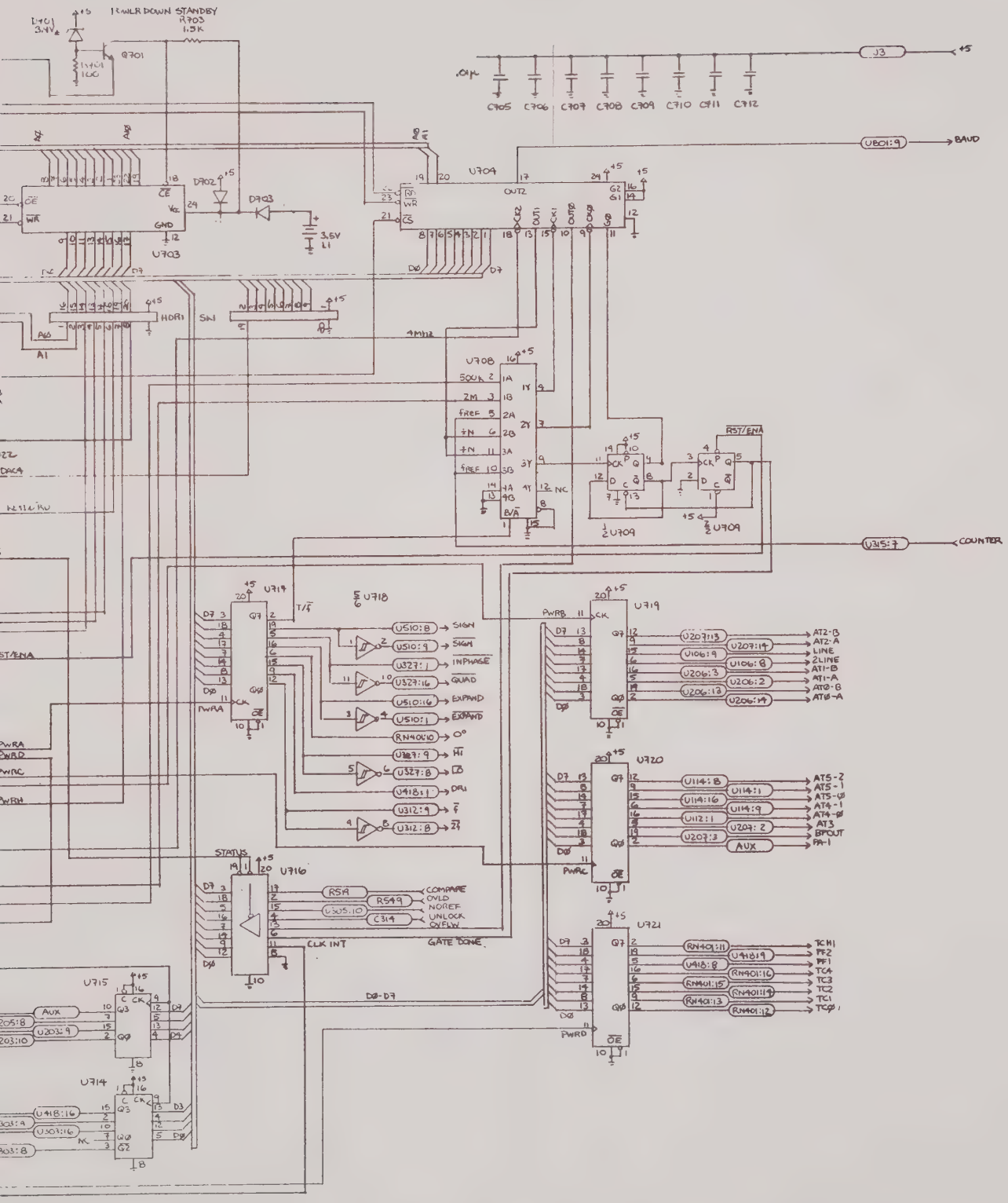


U6101, U6102, U6103	ICM7211AMIPL
U6104, U6105, U6106	CD4030
U6107	74HC374
U6108	74HC175
U6109	74HC244
U6110 - U6118	74LS14A

STANFORD RESEARCH SYSTEMS	FRONT PANEL			
DRAWN 4/23/86	SIZE	FSCM NO.	DWG. NO. SR530-13	REV. A
ISSUED	SCALE JCW		SHEET 6-1	

BISHOP GRAPHICS, INC. REORDER NO. 1860


MREQ
A2
A1
A0
RD
WR
WAIT
U801:13
U801:10
U710:3
R702 4.7K
U701
MREQ
RD
WR
NMI
BUSRQ
WAIT
RFSH
HALT
BUSAK
RESET
INT
M1
IORQ
D7
D6
D5
D4
D3
D2
D1
D0
A15
A14
A13
A12
A11
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1
A0
U702
ROM (WR)
U705
U706
U707
U502:13
U505:9
U503:11
U509:1
U802:3
U804:11
U804:9
U803:9
U506:13
CLK RST
2MHz
4MHz
1MHz
U601:20
U805:3
U802:6
4.0MHz
C701 22Dp
R706 10K
R707 10K
C702 22p
U712
500Khz
976hz
INT2
INT1
U802:40
U801:19
INT
R705 1K
U713
U33:13
408 hz
244hz
U15:5
CLR INT
POWER DOWN RESET
POWER UP RESET
R711 10K
R710 1M
R709 10K
R708 220K
C703 1K
C704 1K
Q703
Q702
RESET
U802:19
U801:21

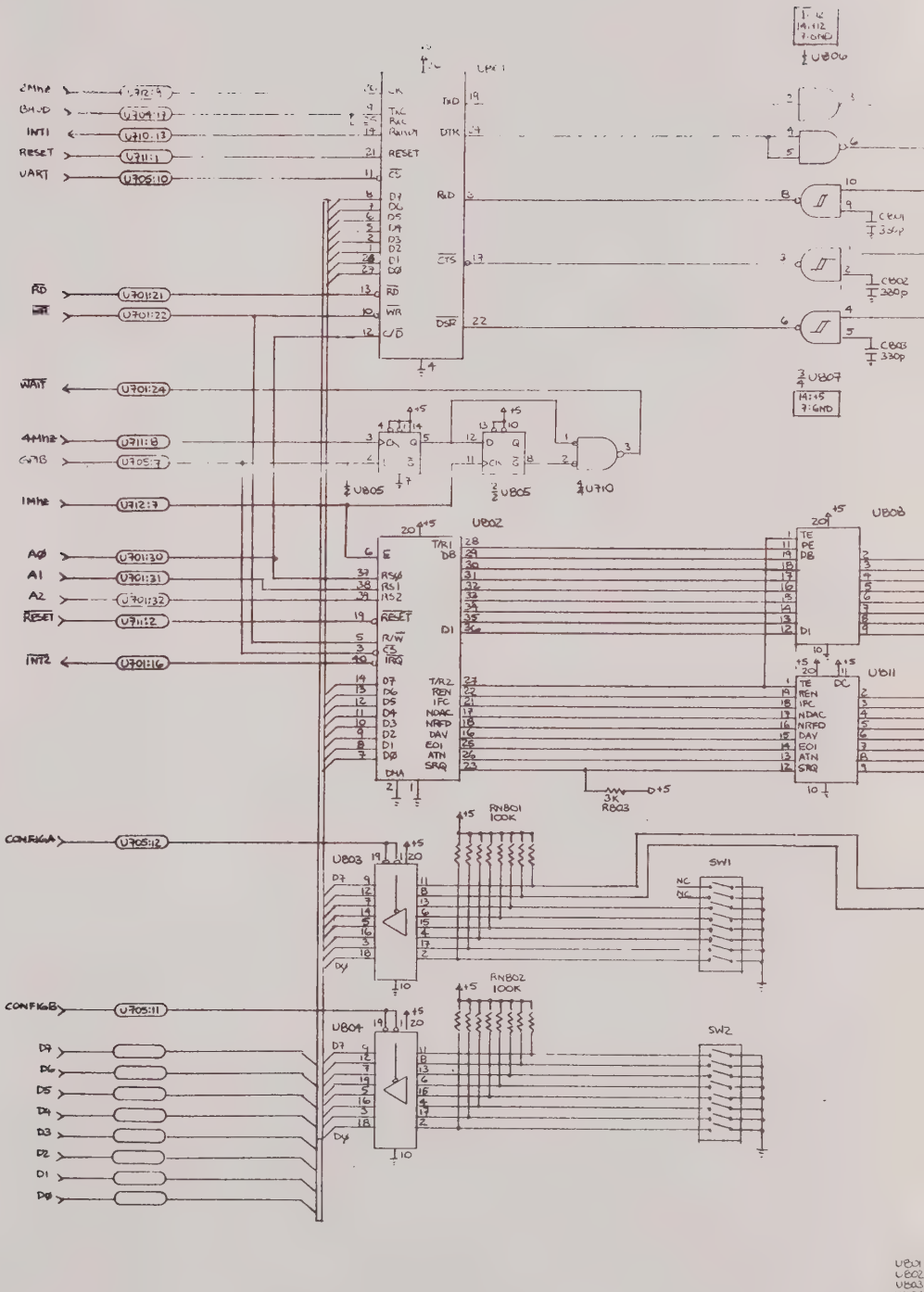


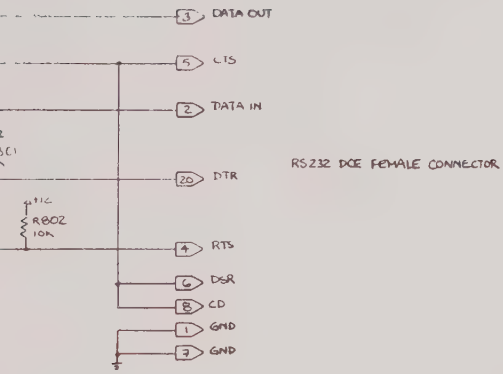
U701	2804	U711	74HCU04	U721	74HC374
U702	27128	U712	74HC4040	U722	74HC32
U703	6116LP	U713	74HC74		
U704	8253	U714	74HC175		
U705	74HC138	U715	74HC175		
U706	74HC138	U716	74HC244		
U707	74HC138	U719	74HC374		
U708	74HC157	U720	74HC14		
U709	74HC74	U719	74HC374		
U710	74HC32	U720	74HC374		

STANFORD RESEARCH SYSTEMS	MICROPROCESSOR CONTROL		
DRAWN 9-28-84	SIZE	FSCM NO.	DWG. NO. SR500-7 REV. B
ISSUED	SCALE	JCW	SHEET 7

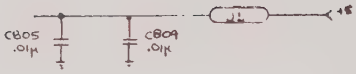
BISHOP GRAPHICS, INC. REORDER NO 1860

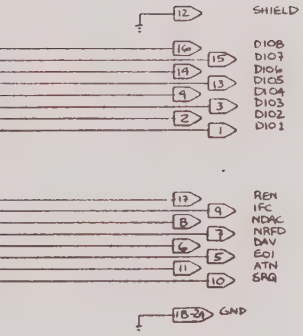
UPDATED 2-22-85


2MHz
BAUD
INT1
RESET
UART
RD
WR
WAIT
4MHz
CLK
1MHz
A0
A1
A2
RESET
INT2
CONFIGA
CONFIGB
D7
D6
D5
D4
D3
D2
D1
D0
U801
U802
U803
U804
U805
U806
U807
U808
U809
U810
U811
SW1
SW2
RNB01
100K
RNB02
100K
3K
RB03
+5
GND

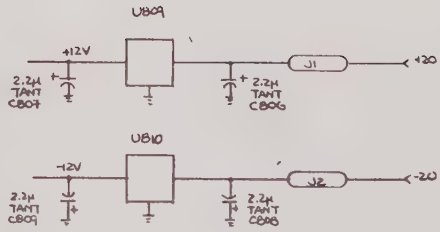


RS232 DCE FEMALE CONNECTOR



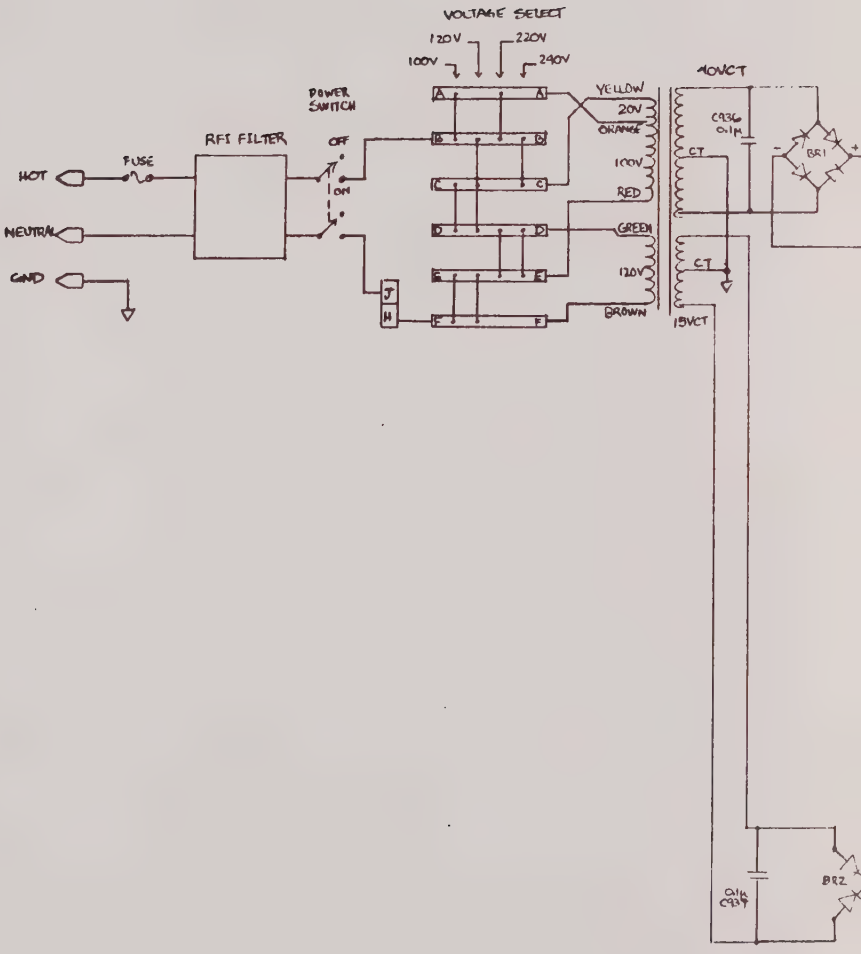


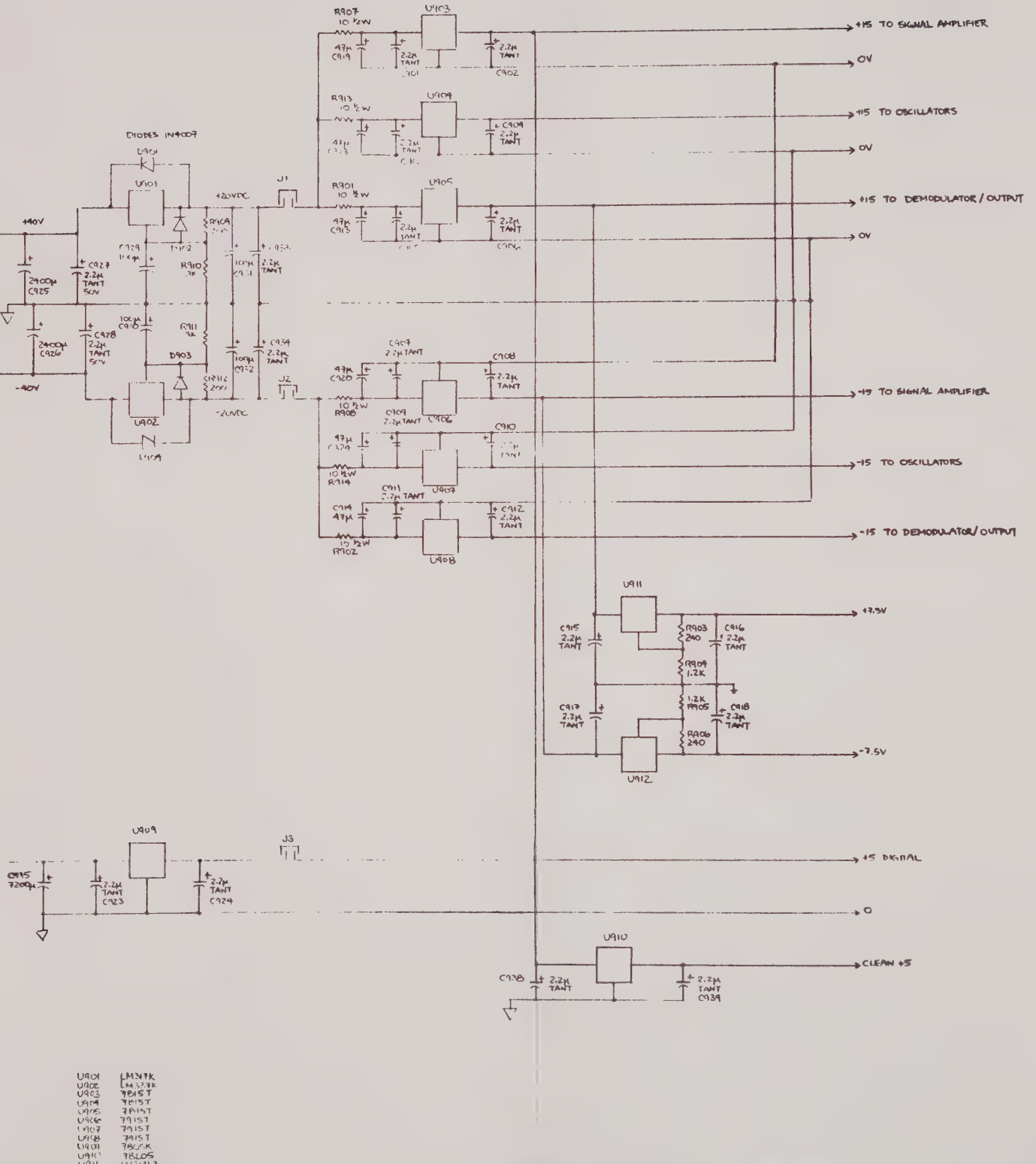
GPIB CONNECTOR



STANFORD RESEARCH SYSTEMS	COMMUNICATIONS INTERFACE			
DRAWN 9-20-84	SIZE	FSCM NO.	DWG. NO. SR500-8	REV. B
ISSUED	SCALE	JCW	SHEET 8	

BISHOP GRAPHICS, INC. REORDER NO. 1860


VOLTAGE SELECT
120V
220V
100V
240V
POWER SWITCH
RFI FILTER
OFF
ON
FUSE
HOT
NEUTRAL
GND
YELLOW
20V
ORANGE
100V
RED
GREEN
120V
BROWN
40VCT
CT
CT
15VCT
C936
0.1M
BR1
BR2
0.1M
C936

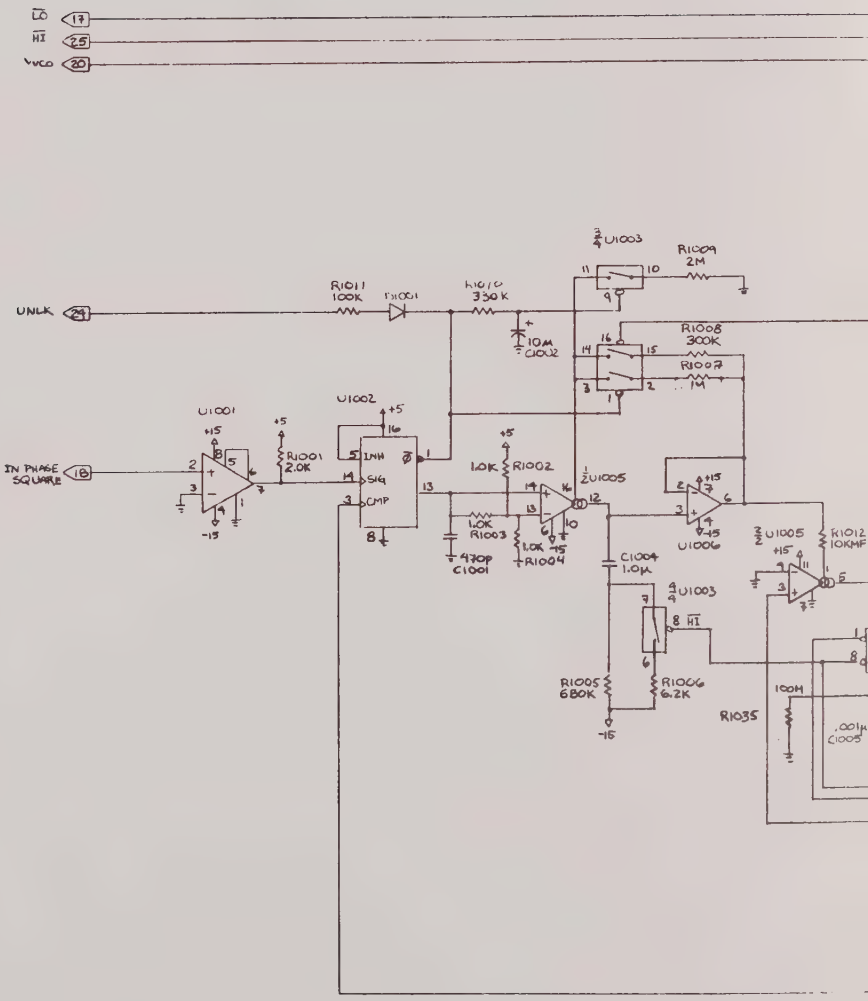


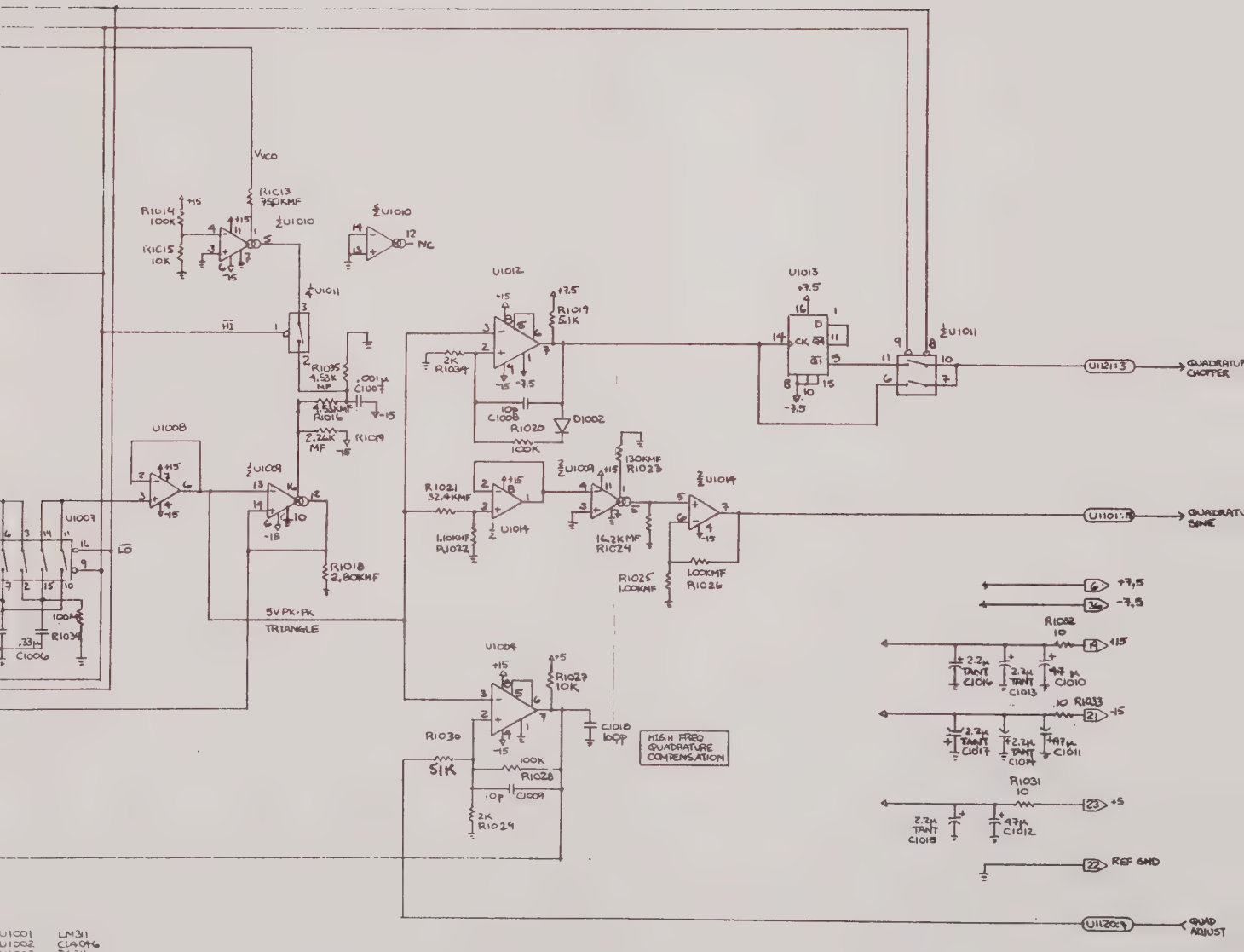
U901	LM317K
U902	LM337K
U903	7815T
U904	7915T
U905	7815T
U906	7915T
U907	7915T
U908	7915T
U909	7805CK
U910	78L05
U911	LM317LZ
U912	LM337LZ

STANFORD RESEARCH SYSTEMS		POWER SUPPLY		
DRAWN 9-30-84	SIZE	FSCM NO.	DWG. NO. SR500-9	REV B
ISSUED	SCALE	JCW	SHEET 9	

BISHOP GRAPHICS, INC. REORDER NO 1860

MODIFIED DEC 5, 1985 REV. C

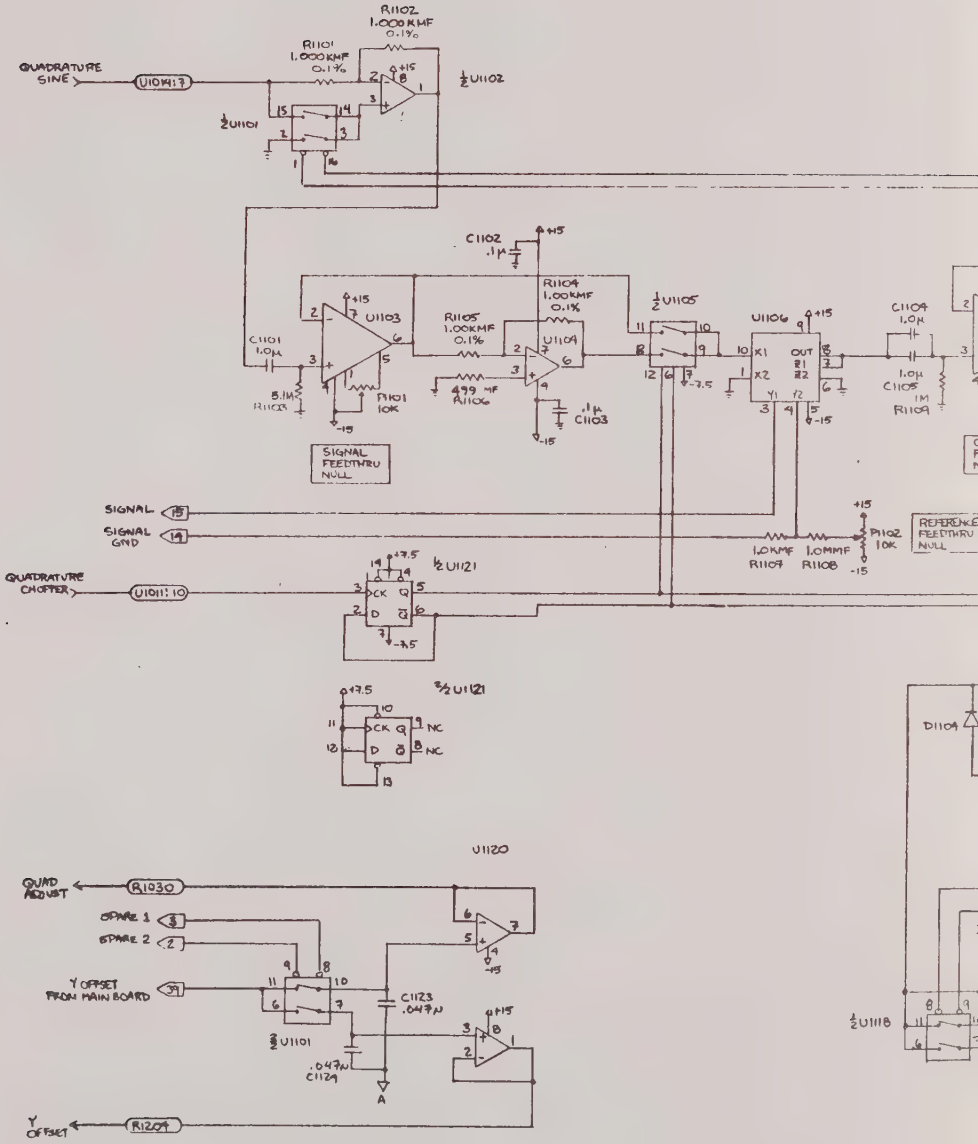

LO
HI
VVCO
UNLK
IN PHASE SQUARE
U1001
U1002
U1003
U1005
U1006
R1001 2.0K
R1002
R1003
R1004
R1005 680K
R1006 6.2K
R1007
R1008 300K
R1009 2M
R1011 100K
R1012 10KMF
R1035
C1001 470P
C1002 10M
C1004 1.0μ
C1005 .001μ
D1001
INH
SIG
CMP
+5
+15
-15
1.0K
100M



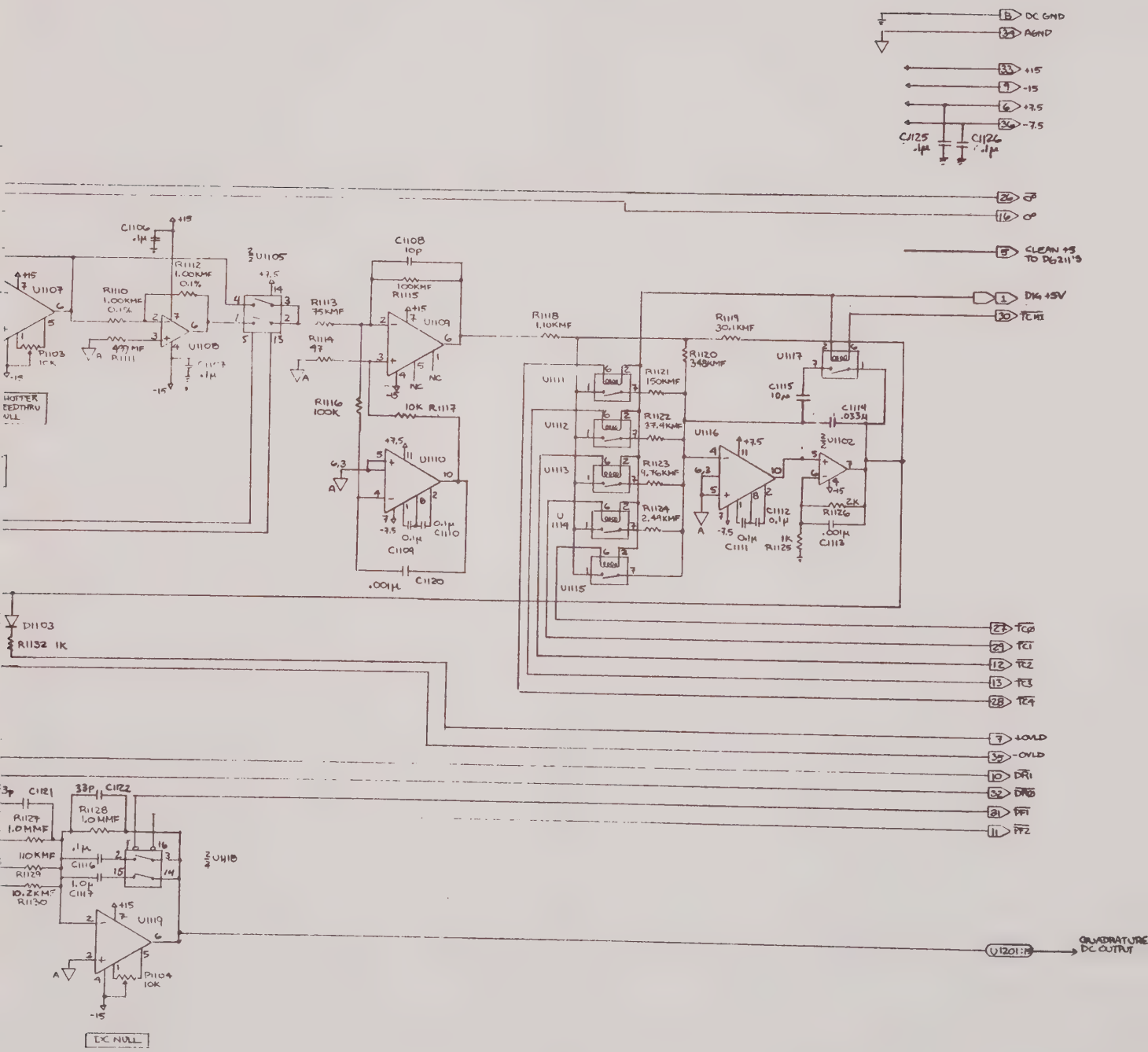
U1001	LM311
U1002	CD4016
U1003	PG211
U1004	LM311
U1005	LM13600
U1006	CA3140E
U1007	PG211
U1008	CA3140E
U1009	LM13600
U1010	LM13600
U1011	PG211
U1012	LM311
U1013	CD4013
U1014	LF412

STANFORD RESEARCH SYSTEMS	QUADRATURE OSCILLATOR		
DRAWN 9-25-84	SIZE	FSCM NO.	DWG. NO. SR530-10 REV. B
ISSUED	SCALE	JCW	SHEET 10

BISHOP GRAPHICS, INC. REORDER NO. 1860

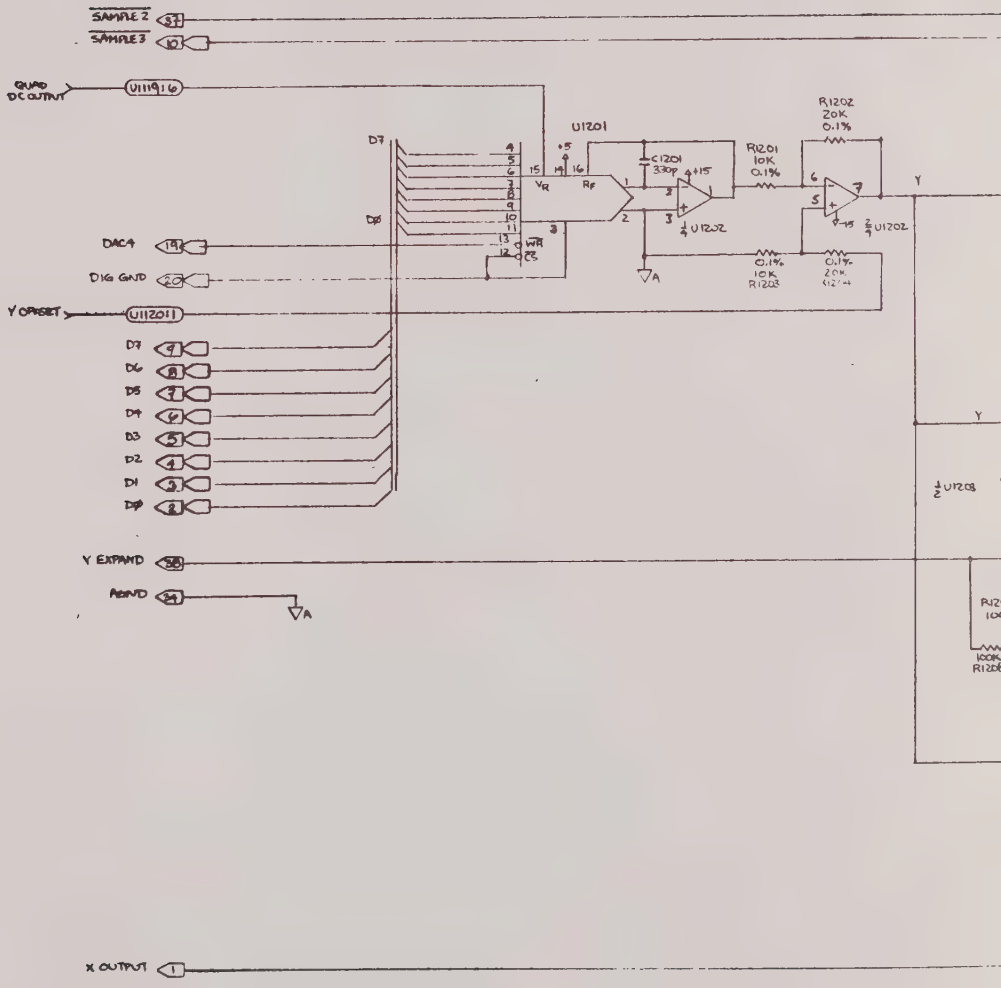


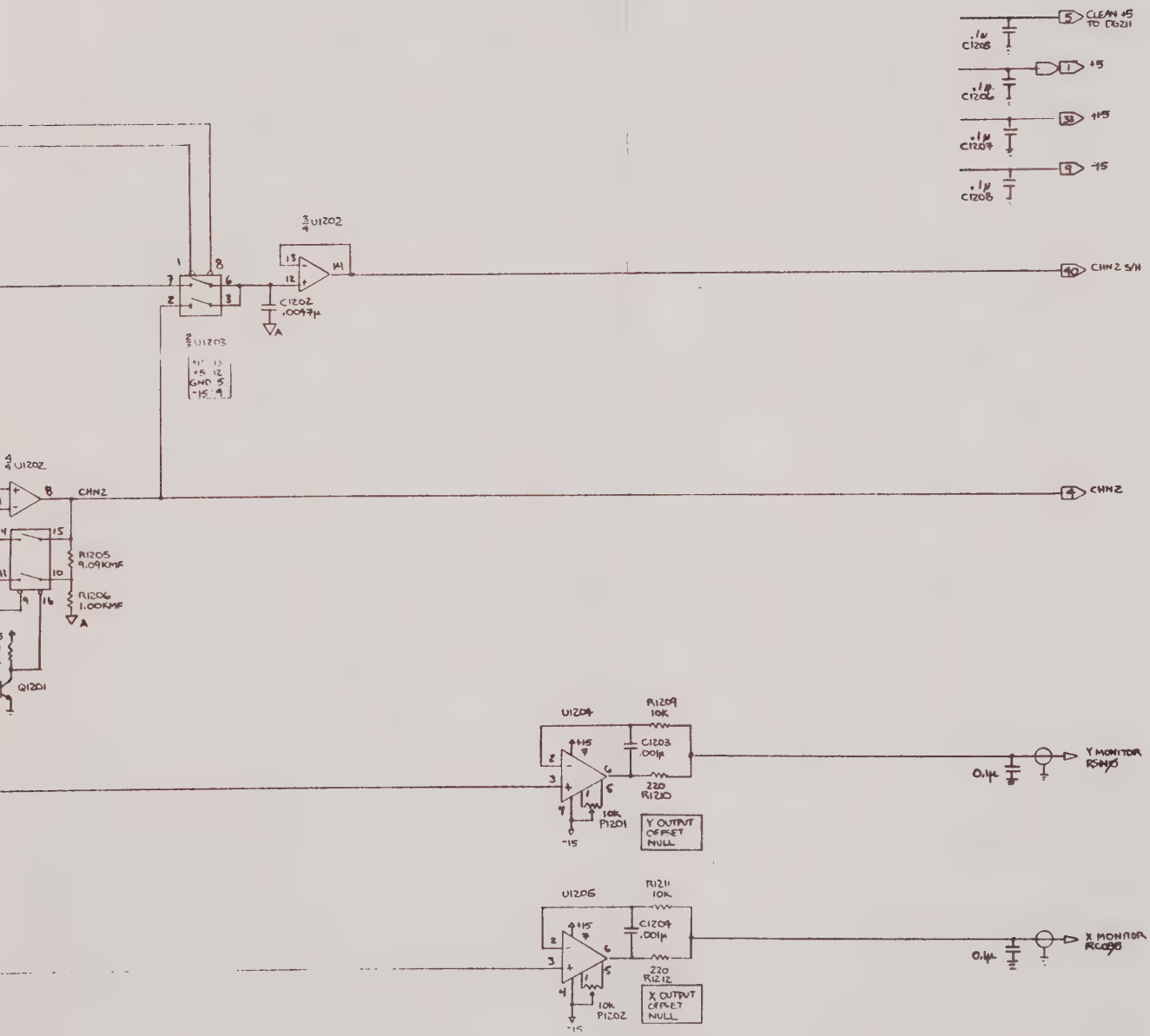
U1101	D6211
U1102	LF412
U1103	LF411
U1104	LT1079
U1105	CD4066
U1106	ADS7811
U1107	LF411
U1108	LT1079
U110A	LF411
U1110	ICL7660



STANFORD RESEARCH SYSTEMS		DEMODULATOR / LOW PASS AMP		
DRAWN 9-29-84	SIZE	FSCM NO.	DWG. NO. SR530-11	REV. A
ISSUED	SCALE	JCW	SHEET 11	

BISHOP GRAPHICS, INC. REORDER NO. 1860


SAMPLE 2
SAMPLE 3
QUAD DC OUTPUT
U1119 16
U1201
D7
D0
DAC4
DIG GND
Y OFFSET
U1120 11
D7
D6
D5
D4
D3
D2
D1
D0
Y EXPAND
ANYD
X OUTPUT
+5
+15
C1201 330p
R1202 20K 0.1%
R1201 10K 0.1%
R1203 10K 0.1%
R1204 20K 0.1%
1/4 U1202
2/4 U1202
1/2 U1203
WR
CS
Y
A



STANFORD RESEARCH SYSTEMS	OUTPUTS			
DRAWN 9-27-84	SIZE	FSCM NO.	DWG. NO. SR530-12	REV. A
ISSUED	SCALE	JCW	SHEET 12	

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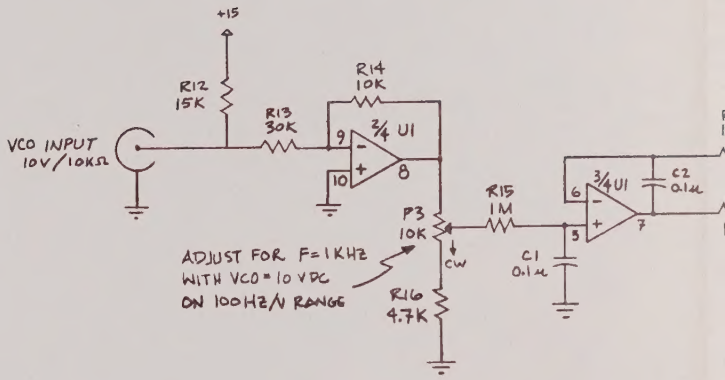
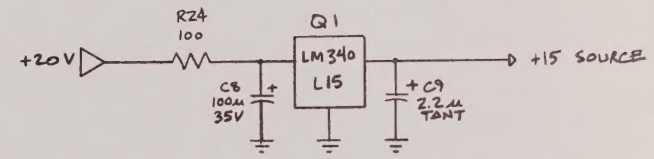
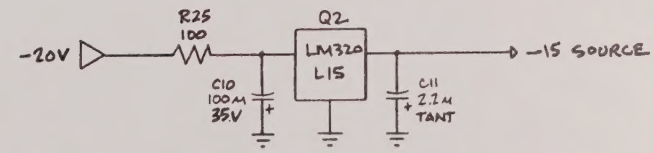
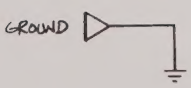
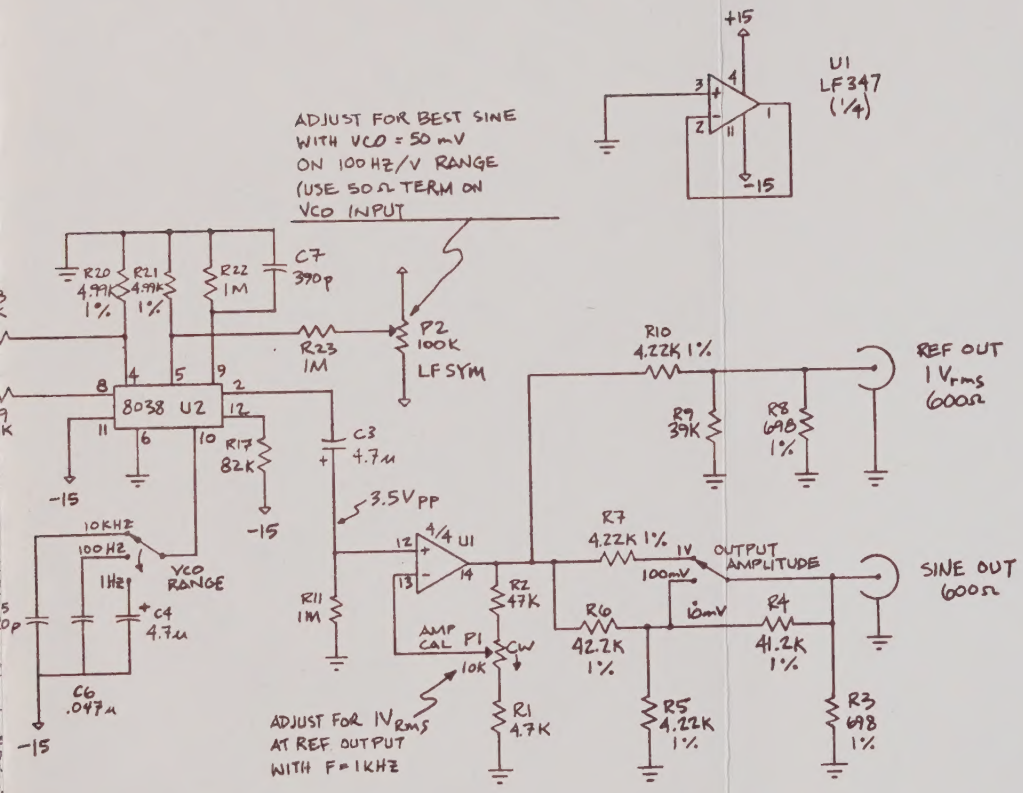

+15
R12
15K
R13
30K
R14
10K
VCO INPUT
10V/10KΩ
3/4 U1
9
10
8
P3
10K
CW
R16
4.7K
ADJUST FOR F=1KHZ
WITH VCO=10 VDC
ON 100HZ/V RANGE
R15
1M
C1
0.1μ
3/4 U1
6
5
7
C2
0.1μ


+20V
R24
100
Q1
LM340
L15
C8
100μ
35V
+C9
2.2μ
TANT
+15 SOURCE


-20V
R25
100
Q2
LM320
L15
C10
100μ
35V
C11
2.2μ
TANT
-15 SOURCE


GROUND



STANFORD RESEARCH SYSTEMS	INTERNAL REFERENCE OSCILLATOR			
	SIZE	FSCM NO.	DWG. NO. SR500-17	REV. B
DRAWN AWR				
ISSUED JRW	SCALE		Aug. 26-1985	SHEET

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REORDER NO. 1860

MP MASTER
MA30345